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NORFOLK AND ENVIRONS: A LAND USE PERSPECTIVE

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U.S. Geological Survey

FINAL REPORT—VOLUME 2, PART A
CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE (CARETS) PROJECT

1125A

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1975

NORFOLK AND ENVIRONS: A LAND USE PERSPECTIVE

An investigation demonstrating applications of remote sensing data from satellites and aircraft to land use analysis and environmental monitoring

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Reston, Virginia

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Preface

This report, like most scientific papers, is a report on work "in progress." Its writing was suggested by sponsors and advisers, who with good reason questioned the authors' announced strategy of tackling a complex land use and environmental information system experiment for the entire 74,712 km^2 (28,846 mi^2) Central Atlantic Regional Ecological Test Site (CARETS). As a step toward developing the information analysis techniques for the larger region, a smaller "prototype" area was selected for testing procedures for gathering and analyzing the remote sensing data, developing appropriate machine processing methods, and presenting the results for evaluation. The Norfolk area, comprising 2.5 percent of CARETS, was selected for this purpose.

Because of the nature of the investigation, an experiment seeking to adapt satellite-derived land information to the problem-solving needs of a region, the authors hope that this interim report will draw quick response from those wanting to have an input into recommendations affecting the information needs of either Norfolk or the CARETS region. And since the investigators hope that the CARETS experiment will provide useful design for regional monitoring and analysis efforts elsewhere, readers whose interests lie outside CARETS may wish to make comments or recommendations concerning the project design, analytical methodology, or results.

Sponsors will notice that the report contains no recommendations or conclusions concerning the operational uses of LANDSAT and aircraft sensors as they might be applied to the longer range land resources analysis and environmental monitoring. This omission was intentional, so that the results obtained from comparisons of data from the two sources could speak for themselves, with readers assisting authors in the drawing of such conclusions at this time. Such recommendations and conclusions are presented in other volumes of the CARETS final report.

The authors wish to acknowledge the contributions of several individuals who provided invaluable assistance at various stages in the CARETS program. The late Edward A. Ackerman provided guidance and inspiration throughout the early phases of the CARETS and Norfolk investigations. His death in 1973 left near completion a contribution he was preparing, in which he foresaw CARETS and the other NASA/USGS demonstration projects evolving into a national land use information service. Administration and management throughout the project were provided by the U.S. Geological Survey's Chief Geographers: Arch C. Gerlach, until his death in 1972, and James R. Anderson afterward. James R. Wray of the USGS Geography Program designed the map layout and indexing scheme, keyed to the UTM grid system, and in addition contributed valuable advice and assistance throughout the project. Robert Dolan and H. Grant Goodell of the University of Virginia provided valuable design and conceptual advice at the project formulation stage, and Dolan remained a key adviser throughout. Brian J. L. Berry of the University of Chicago read the final manuscript and provided valuable advice. William B. Mitchell served as coinvestigator on the CARETS project until he was reassigned as Chief of the newly formed Geographic Information Systems Branch within the Geography Program. Ivan Hardin managed the original photointerpretation efforts for CARETS and Peter DeForth devised methods of field checking, change detection using LANDSAT, and wrote portions of Chapter II. Eldon Jessen managed the final cartographic effort in preparing manuscript maps for open file release. Sherman K. Neuschel compiled the Earth Materials Map, and its interpretation in terms of land use applications.

Other USGS colleagues who made contributions along the way include Susan Moorlag, Kenneth Ferguson, Karen Letke, Cheryl Hallam, Virginia Carter, Edward Pluhowski, and Harold Guy. John Lewis of the University of Maryland and Wallace Reed of the University of Virginia conducted the study on air quality management.

Special thanks are due to Robert Foeller and Arthur Collins, Executive Director and Director of Planning, respectively, of the Southeastern Virginia Planning District Commission, Norfolk. They opened their offices to our research teams, and provided valuable information and recommendations from the viewpoint of a principal user agency. Advice on development of the information system and testing user response was contributed by members of the International Geographical Union Commission on Geographical Data Sensing and Processing, particularly Roger F. Tomlinson, Duane F. Marble, and Hugh Calkins. Sponsor representatives and monitors who gave valued advice and assistance were Wayne Mooneyhan and Armand Joyce of NASA, Scott Sollers of the Army Corps of Engineers, and Charles Withington of the EROS Program, Department of the Interior. Funding support came primarily from NASA, with additional support from the EROS Program and the USGS Geography Program. Finally, the authors are most appreciative of the skill and persistence of Kate Cook, Carolyn Powers, Cindy Cunningham, and Darleen Stanton, without whom there would have been no typed manuscript.

LIST OF FINAL REPORT VOLUMES

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NORFOLK AND ENVIRONS: A LAND USE PERSPECTIVE

An investigation demonstrating applications of remote sensing data from satellites and aircraft to land use analysis and environmental monitoring

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By Robert H. Alexander, Peter J. Buzzanell, Katherine A. Fitzpatrick, Harry F. Lins Jr., and Herbert K. McGinty, III.

Abstract

The Norfolk-Portsmouth Standard Metropolitan Statistical Area (SMSA) in southeastern Virginia was the site of intensive testing of a number of land resources assessment methods, built around the availability of remotely sensed data from the Earth Resources Technology Satellite (ERTS-I), later renamed LANDSAT I. The Norfolk tests were part of a larger experiment known as the Central Atlantic Regional Ecological Test Site (CARETS), designed to test the extent to which LANDSAT and associated high-altitude aircraft data could be used as cost-effective inputs to a regional land use information system.

The Norfolk SMSA contains a variety of land uses typical of the urbanized eastern seaboard, along with typical associated problems: rapid urbanization; heavy recreational, commercial, and residential demands on fragile beaches and coastal marsh environments; industrial, transportation, and governmental land and water uses impacting on residential and agricultural areas; drainage and land stability difficulties affecting construction and other uses; and increasing difficulties in maintaining satisfactory air and water quality.

Land use and land cover data at three levels of detail (Level I, most aggregated; Level III, most detailed) were derived by manual image interpretation from both aircraft and satellite sources and used to characterize the 1,766-km^2 (682-mi^2) SMSA from the perspective of its various resource-related activities and problems. Measurements at Level I from 1:100,000-scale maps revealed 42 percent of the test area (excluding bays and estuaries) to be forest, 28 percent agriculture, 23 percent urban and built-up, 4 percent nonforested wetlands, and 2 percent water. At the same scale and level of detail, 10 percent of the SMSA underwent change from one land use category to another in the period 1959-1970, 62 percent of which involved the relatively irreversible change from forest or agriculture to urban uses. Digitization and machine processing of line data from land use maps facilitated these and other area measurements and comparisons.

CARETS research found the traditional concepts of map accuracy to be not exactly applicable to assessments and comparisons of land use maps derived from aircraft and LANDSAT remote sensor data. The investigation included field observations and a variety of photo and image sampling methods for accuracy assessments. With the exception of urban-rural fringe areas where complex intermixtures occur, most Level I land use categories can be accurately interpreted using LANDSAT imagery.

The aircraft data used in this study (color infrared photography at a scale of 1:120,000) provide more detailed land use information than LANDSAT data (in the form of color composite enlargements to scales of 1:100,000 and 1:250,000). The greater detail, however, is obtained at increased costs. Aircraft data interpretation and editing costs (exclusive of field checking, digitizing and publication costs) for producing Level II land use coverage of the SMSA at a scale of 1:100,000 amounted to $1,824 (1973 dollars), or $0.92 per km^2 ($2.38 per mi^2). Similar costs for Level I coverage for LANDSAT, at a scale of 1:250,000 amounted to $150, or $0.08 per km^2 ($0.20 per mi^2).

The CARETS project demonstrated applications of the land use information in regional problem solving in examples of air quality planning, transportation planning, land use planning, and coastal zone management. The project also produced a new earth materials map, depicting surficial geologic conditions as they affect land capability and suitability. These maps in turn serve as complementary data to aid in interpretation of land use prospects. CARETS investigators conducted this study in cooperation with the staff of the Southeastern Virginia Planning District Commission, who evaluated the data and results as applied to regional planning activities in the SMSA. In addition, several Federal, State and local user agencies assisted in evaluating the study results.

CHAPTER 1

CARETS BACKGROUND AND SUMMARY DESCRIPTION: NORFOLK AS PROTOTYPE

The Central Atlantic Regional Ecological Test Site (CARETS) is one of the original sites designated in 1970 by the National Aeronautics and Space Administration (NASA) for detailed evaluations of the Earth Resources Technology Satellite, now known as LANDSAT, and correlative aircraft and ground data by multidisciplinary teams. Sponsored jointly by NASA and the U.S. Geological Survey (USGS), the CARETS project was formulated during 1970 and 1971 in the USGS Geographic Applications Program (now the Geography Program of the Land Information and Analysis Office), and, as a NASA-sponsored LANDSAT experiment, was initiated formally on July 1, 1972.

CARETS boundaries, as delimited on figure 1-1, were established after consultation with State and Federal agencies. Decisions were based upon the extent of urbanized land, the boundaries for the Corps of Engineers Chesapeake Bay Study Area, the reasonable size for aircraft and satellite data collection and the need for dividing the area into subunits compatible with census data and planning regions. The 74,712-km^2 (28,846-mi^2) CARETS area consists of 74 counties, 18 independent cities and the District of Columbia.

The primary objective of the CARETS demonstration project is to test the applicability of LANDSAT and related remote sensor data in the development of a regional land resources information system. The rationale and design of the CARETS experimental information system are based on a fact and an assumption. The fact is that land use decisions inevitably lead

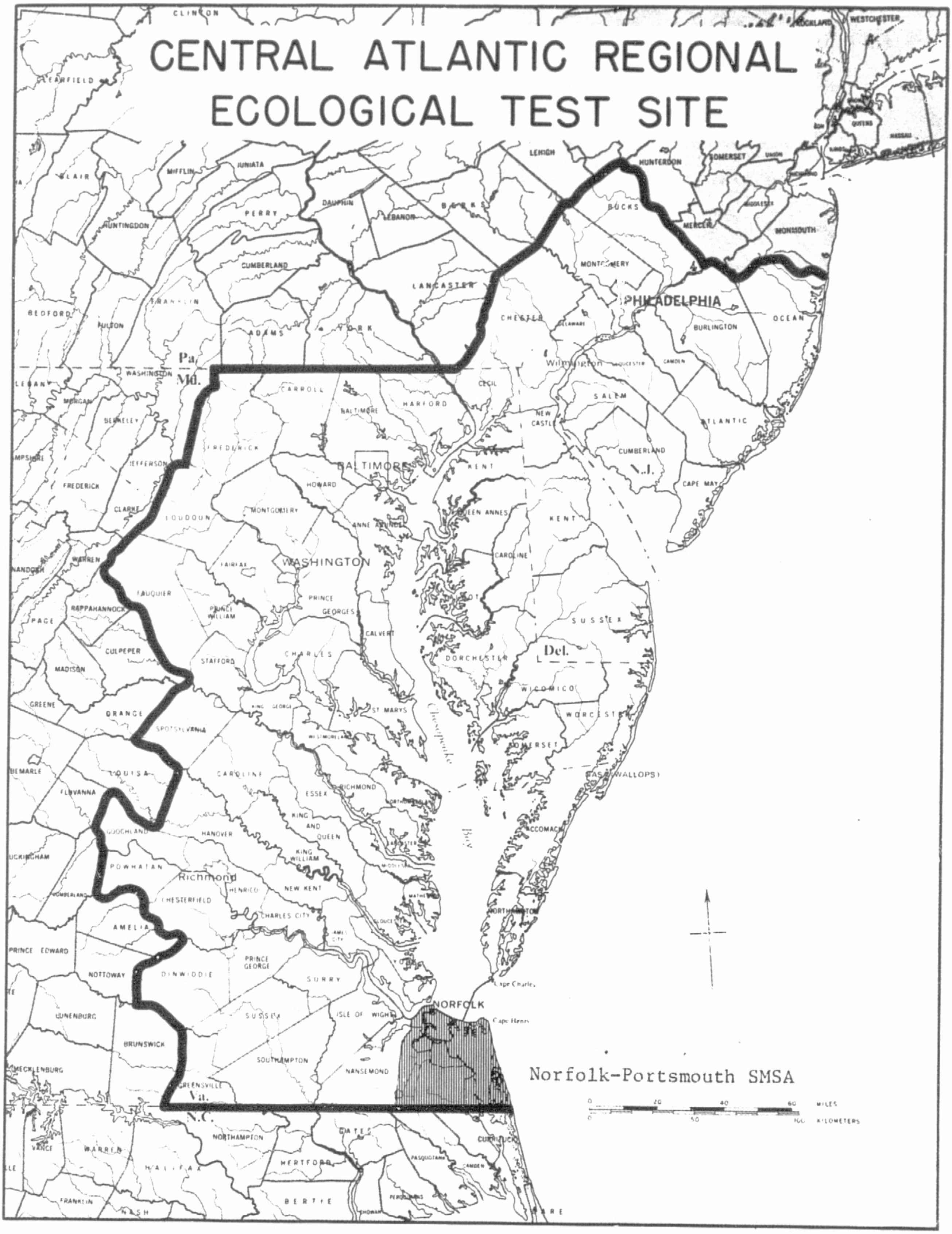

CENTRAL ATLANTIC REGIONAL
ECOLOGICAL TEST SITE
PHILADELPHIA
BALTIMORE
WASHINGTON
Richmond
NORFOLK
Wilmington
Pa.
Md.
Del.
N.J.
Va.
N.C.
Chesapeake
Bay
Cape Charles
Cape Henry
Norfolk-Portsmouth SMSA
0 20 40 60 MILES
0 50 100 KILOMETERS
LANCASTER
YORK
ADAMS
CHESTER
BUCKS
MONTGOMERY
BURLINGTON
OCEAN
SALEM
ATLANTIC
CUMBERLAND
CAPE MAY
CECIL
HARFORD
CARROLL
BALTIMORE
FREDERICK
HOWARD
MONTGOMERY
LOUDOUN
FAIRFAX
PRINCE WILLIAM
FAUQUIER
STAFFORD
PRINCE GEORGES
CALVERT
CHARLES
ST MARYS
KENT
QUEEN ANNES
CAROLINE
DORCHESTER
SUSSEX
WICOMICO
WORCESTER
SOMERSET
ACCOMACK
NORTHAMPTON
CAROLINE
ESSEX
RICHMOND
KING AND QUEEN
KING WILLIAM
HANOVER
HENRICO
NEW KENT
CHARLES CITY
CHESTERFIELD
POWHATAN
GOOCHLAND
LOUISA
SPOTSYLVANIA
ORANGE
CULPEPER
MADISON
RAPPAHANNOCK
WARREN
CLARKE
JEFFERSON
BERKELEY
MORGAN
WASHINGTON
FRANKLIN
FULTON
BEDFORD
CUMBERLAND
PERRY
DAUPHIN
LEBANON
BERKS
JUNIATA
MIFFLIN
HUNTINGDON
BLAIR
LEHIGH
HUNTERDON
SOMERSET
MERCER
MONMOUTH
WESTCHESTER
QUEENS
NASSAU
AMELIA
DINWIDDIE
PRINCE GEORGE
SURRY
SUSSEX
ISLE OF WIGHT
SOUTHAMPTON
NANSEMOND
NOTTOWAY
LUNENBURG
BRUNSWICK
GREENSVILLE
MECKLENBURG
PRINCE EDWARD
FLUVANNA
GREENE
NORTHAMPTON
HERTFORD
GATES
BERTIE
HALIFAX
WARREN
VANCE
FRANKLIN
NASH
CURRITUCK
PASQUOTANK
CAMDEN

Figure 1-1

to environmental consequences. The assumption is that improved information on the cumulative effects of those decisions, i.e., the mosaic of observable land use patterns and changes, leads to better decisions, improved quality of the environment, and wiser use of our land resources.

Determining whether or not the assumption is true is beyond the scope of this report. The effort described here is concerned only with ways of gathering, processing, and calibrating the information, and making it communicable to users. The basic project design, however, calls for formal interaction with selected users, who may include land use decision makers. Thus later investigators could perhaps test the assumption that improved information leads to better decisions, based on the groundwork established by this project. One of the most rewarding aspects of the experiment has been the learning experience from close involvement with the "users," many of whom are under severe pressures in planning agencies to obtain large quantities of data quickly, to be used in preparing or updating comprehensive local or regional plans.

The basic components of the CARETS project are presented in figure 1-2. Data and data products from remote sensor sources are used to extract land use information, which is produced in the form of maps, measured and summarized by computer, and made available to users. This same land use information, along with other data sets (geologic, hydrologic, political boundary, and socioeconomic), is used for environmental impact analysis and other planning applications. These products were also presented to users for evaluation and use in problem solving. User feedback, in turn, should govern the type of data and products produced in later phases of the information system.

CARETS CONCEPT DIAGRAM

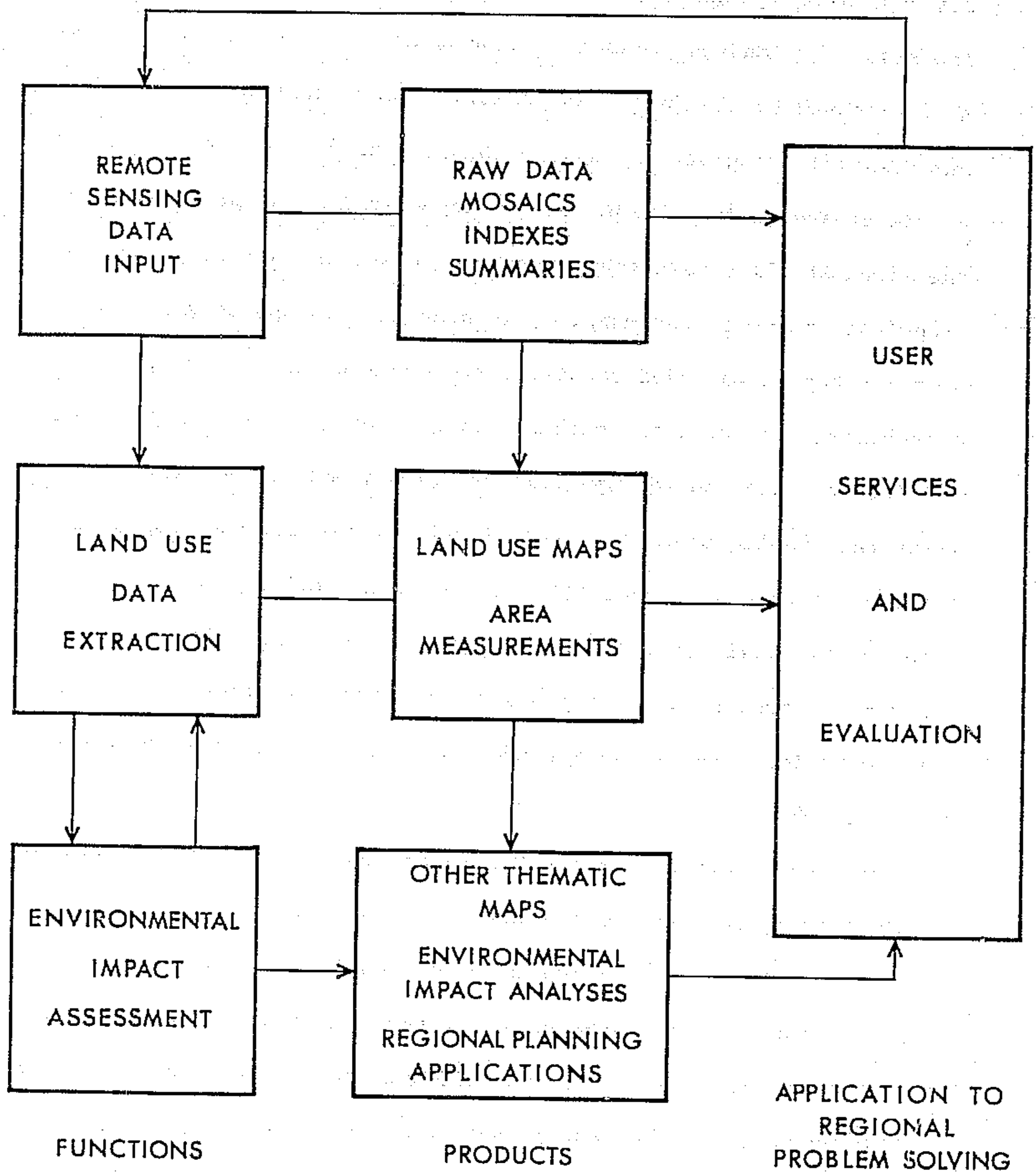


Figure 1-2

CARETS land use has been mapped at a scale of 1:100,000 from high-altitude aircraft photography and at a scale of 1:250,000 using LANDSAT imagery. The land use classification scheme used is an early version of that proposed by the Interagency Steering Committee on Land Use Information and Classification presented in USGS Circular 671 (Anderson and others, 1972) and is presented in outline form in appendix A. The proposed revision of the Circular 671 classification scheme, based on user response and on experience using it for mapping, is presented in appendix B. The classification may be extended to different levels of detail, appropriate for different scales and data sources; Levels I and II, used in the mapping of CARETS, are intended for specific use with remote sensor data. To illustrate applications at higher levels of detail, the CARETS project has developed a proposed Level III classification and applied it on an experimental basis to the Norfolk test site (appendix C). USGS Geography Program researchers developed a similar Level III classification scheme for use in identifying the manmade causes of ground water pollution (appendix D).

Three major aspects of the CARETS project are the development of an information system, the user evaluation program, and the assessment of environmental impact. A geographic information system will not only allow for automatic measurement and summation of data sets but also for the retrieval of updated and overlaid data sets. The goal of the user evaluation program is to expose potential users to a wide variety of CARETS products and to receive and evaluate user feedback relating to the utility and desirability of such products, given cost considerations. Finally, in keeping with the primary objectives of CARETS, the project is concerned with the use of interpreted data derived from remote sensors to help assess the environmental impact of land use change.

OBJECTIVES AND SCOPE OF THE NORFOLK PROTOTYPE

One of the early discussion points in the development of the CARETS project was the size of the area to be encompassed by the experiment in order to provide a meaningful test of the concepts. On the one hand, there was a need for a region large enough for a "volume" test of mapping and information processing so that technical procedures and cost factors could be extrapolated to larger regions or to the whole United States. On the other hand, there was a need for a "micro" evaluation of all data gathering, verification, processing, display, and use factors for a small enough field site to allow all the complexities of the project model to be fully explored. The CARETS investigators and sponsor representatives jointly agreed on a procedure that was a compromise between these positions: The Norfolk test site, at the southeastern extremity of CARETS, was selected as a workable prototype for testing the project concepts and displaying the results.

The Norfolk site, having an area of 1,766 km^2 (682 mi^2) was judged suitable for most systems tests, based on project budget, personnel, and time constraints. The test site consists of a standard statistical region for which other data sets are available for comparison, the Norfolk-Portsmouth Standard Metropolitan Statistical Area (SMSA) as defined in the 1970 Census (but not including the recent addition to the SMSA of Nansemond County*, Virginia, and Currituck County, North Carolina). Land use in the test site varies from the highly urbanized Norfolk-Portsmouth core areas to less intensively used agricultural and forest lands to the fragile coastal and marshlands in which intensity of use depends on season and weather. The Norfolk test site thus presents a microcosm of

*now city of Suffolk

land use in CARETS and is an excellent area in which to accomplish the objectives basic to the CARETS model: development of a land resources information system, assessment of the environmental impact applications of land use patterns and change trends, and evaluation of the CARETS products by the southeast Virginia user community.

The development of a land resources information system for the Norfolk test site is based upon the ability to overlay land use and multiple sets of map data. The CARETS graphic-based data sets are listed below:

Graphic-Based Multiple Overlay Components
Of The Norfolk Prototype Package

Rectified Photomosaic (1:100,000) From 1970 High-Altitude Photography

Level I Land Use Map (1:100,000) 1959

Level I Land Use Change Map (1:100,000) 1959-1970

Level II Land Use Map (1:100,000) 1970

Level II Land Use Change Map (1:100,000)1970-1972

Level I LANDSAT Land Use Map (1:250,000) 1972

Census Tract And City Boundary Overlay (1:100,000)

Cultural And Locational Feature Overlay (1:100,000)

Geologic Overlay (1:100,000)

Drainage Basin Overlay (1:100,000)

These sets have been designed for use, both in assessing land use and environmental characteristics and in providing assistance to the user community in their land resources planning and management functions.

This report provides procedural information concerning the compilation, interpretation, and accuracy verification techniques necessary to build the land resources information system data base, and as well, describes the computerized data handling and analysis system used. This system is innovative in that it has the capability to catalog, inventory, correlate, and analyze large volumes of multiple overlay data sets at speeds and complexities not practical by conventional manual methods. To complement the procedural information, a cost analysis for the development of the land resources information system is presented.

This report also provides examples of environmental impact applications of the land resources information system for the Norfolk test site, which form a framework for relating changing land use to environmental conditions. The sample reports are presented to assess geologic, hydrologic, and air and water quality interrelationships associated with land use change. In addition, a comprehensive analysis of land use patterns and change trends is given for the major regional land uses.

An essential part of the CARETS research design includes the evaluation of the land resource information system by the user community. This phase of the CARETS project began with an initial user conference in June 1971. Evaluations of CARETS concepts and the potential of remote sensing as the prime data inventory technique were elicited from users at the time. Interaction with the user community has continued throughout the program, ranging from the development of the CARETS information center at USGS Geography Program to visits by USGS staff members in offices of user agencies throughout the region. A special effort has been made to obtain an evaluation of the Norfolk prototype package from the Southeast Virginia user community. As part of the overall user effort in the Norfolk test site, the CARETS staff has sought to relate the land resource data base to public policy on the Federal, State and local levels by describing governmental programs requiring land resource information relating to present and potential user data needs.

NORFOLK TEST SITE REGIONAL OVERVIEW

Physical and Ecological Description

Regional Climate

The climate of the Norfolk test site is marine temperate. The area's geographic position with respect to principal storm tracks is especially favorable; it lies at the northern end of the warm temperate climatic zone (Trewartha, 1967), south of the average path of storms originating in the higher latitudes and north of the usual track of tropical storms. Winters are mild, and summers, though warm and long, are frequently tempered by cool periods associated with northeasterly winds off the Atlantic. The mean annual temperature from 1950 to 1972 was 15.4°C (59.8°F). January has the lowest mean temperature of 5.3°C (41.5°F) and July has the highest mean temperature of 25.9°C (78.6°F) (table 1-1).

The area's mild marine climate, its strategic location at the entrance of the Chesapeake Bay, and its natural harbor have made it a favorable location for extensive U.S. Navy institutional land use.

From an agricultural standpoint, the area is favored by a long growing season, averaging 235 days and 62 percent average annual sunshine.

Table 1-1--Climatological normals recorded from data at the Norfolk Municipal Airport
[Based on 1950-72 values, U.S. Department of Commerce]

Month	Average degrees F	Air temperature degrees C	Precipitation In.	Precipitation Cm.	Relative humidity	Average MPH	Winds m/sec	Prevailing direction	% sunshine*
Jan.	41.5	5.3	3.25	8.26	66.5	11.9	5.32	SW	50
Feb.	42.3	5.7	3.35	8.51	63.5	12.1	5.41	N	57
Mar.	48.7	9.3	3.69	9.37	68.0	12.8	5.72	NE	60
Apr.	57.4	14.7	3.19	10.18	70.0	12.1	5.41	SW	63
May	66.7	19.8	3.64	13.25	81.0	10.8	4.83	SW	66
June	74.7	23.7	4.05	16.40	72.7	10.0	4.47	SW	66
July	78.6	25.9	5.73	14.55	78.7	9.5	4.25	SW	66
Aug.	77.5	25.3	5.43	13.87	79.7	9.4	4.20	NE	66
Sept.	72.4	22.4	3.87	9.82	84.5	10.0	4.47	NE	63
Oct.	61.3	16.3	3.15	8.00	74.7	10.8	4.83	NE	64
Nov.	52.0	11.1	2.59	6.71	75.5	11.3	5.05	SW	60
Dec.	43.6	6.4	3.18	8.07	74.2	11.3	5.05	SW	52
Totals and Average	59.8		45.12		74.2	11.0	4.92	SW	62

*Percent possible sunshine

The average date of the last freezing temperature in spring is March 25, while the average date of the first frost in autumn is November 18 (Virginia Crop Reporting Service, 1973). Precipitation is well distributed throughout the year. The mean annual precipitation between 1950 and 1972 was 114.6 cm (45.1 inches). July has the highest mean precipitation of 14.6 cm (5.73 inches) and November the lowest with 6.58 cm (2.59 inches).

Relative humidity varies throughout the day and with the season, though mean night humidity values are 7 percent higher than daytime values for all months. The mean annual relative humidity between 1950 and 1972 was 74.2 percent. The highest mean relative humidity, 84.5 percent, occurs in September and the lowest 63.5 percent occurs in February.

Wind speed is least in July and August with mean values of 4.29 and 4.16 m/s (9.6 and 9.3 mi/h), respectively. February has the highest monthly wind speed, 6.39 m/s (14.3 mi/h). Mean annual wind speed is 5.36 m/s (12.0 mi/h).

These climatological data are included, along with other meteorological data sets in chapter 4, to illustrate their use in several aspects of the environmental impact implications of land use patterns and changes. Not only are such benchmark data useful in measuring changes but also for determining the relationships of weather to water turbidity, photosynthesis, air quality, and ultimately land use. Data on the prevalence of sunshine and relative humidity are useful in planning remote sensing data-gathering missions, which have been the sources of the land use data contained in this report.

Landforms and Earth Materials

The relationship between man and his geologic habitat is vital and fundamental. This "Landforms and Earth Materials" section of the study is concerned with problems associated with man's use of the Earth and the reactions of the Earth to that use, with emphasis on the physical properties of earth materials that affect agriculture and engineering work. The necessity for this type of study will become increasingly apparent as the pressure of urban growth and the competition for land continues. This report will discuss the environmental impact applications of geomorphic data later. First, however, it will present an overview of landforms and earth materials. The rationale for such a discussion is similar to that of the previous section, namely, that a base-line or benchmark description of a region is necessary for the later assessment of the magnitude and direction of changes.

The broad geomorphic character of the Norfolk test site is that of a low flat coastal plain with slopes rarely exceeding 5 degrees, presenting few nonwater barriers. More specifically, the topography of the region can be characterized by low elevations and relief consisting of a series of wide, gently eastward-sloping plains separated by linear, eastward-facing scarps. The landforms have a north-south trend closely related to the depositional morphology of ancient barrier beach and lagoonal environments.

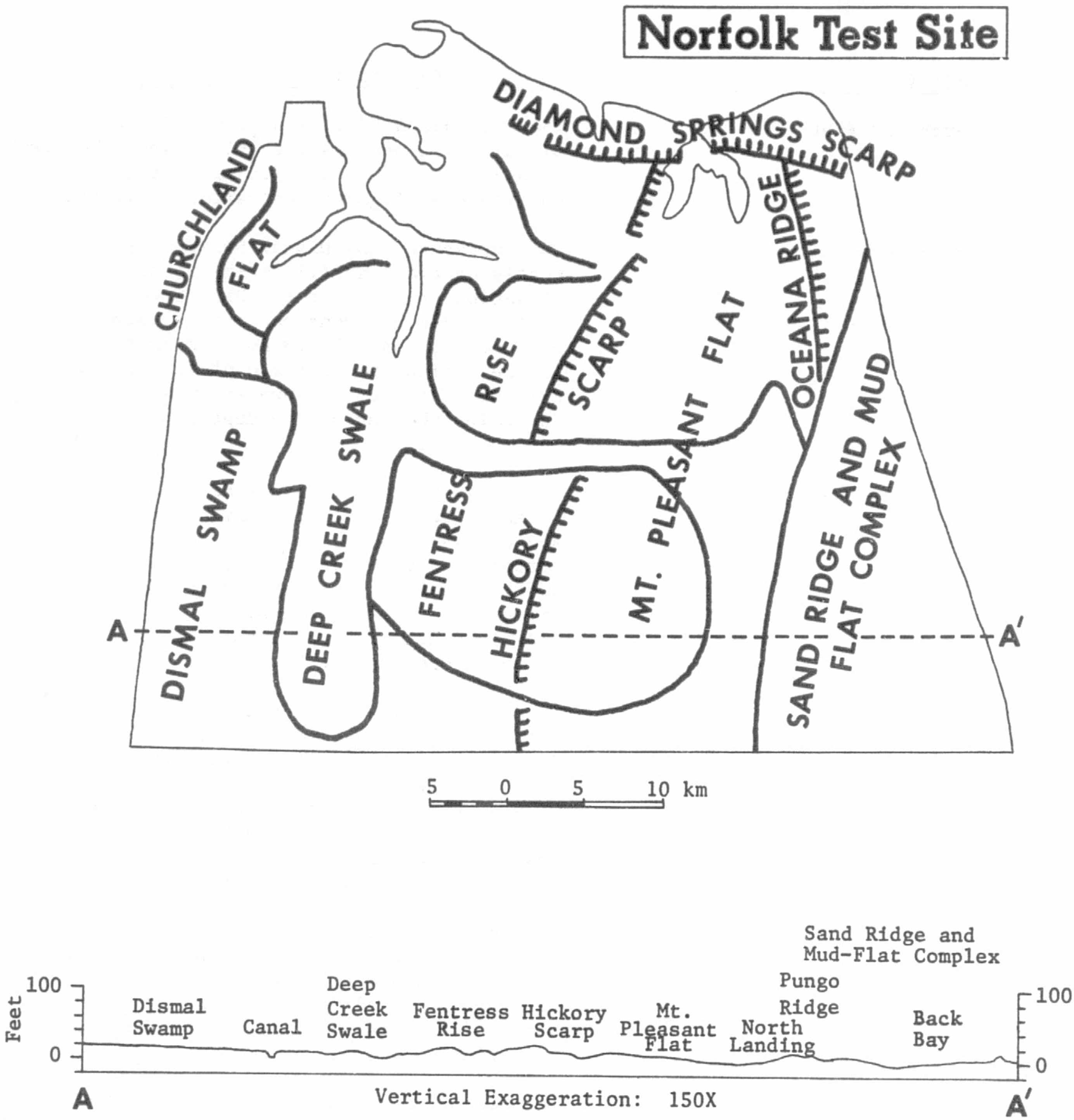
Wentworth (1931) has described the area according to the terrace formation concept, but this system of subdivision has been abandoned because delineated stratigraphic units are not confined to any one particular geomorphic feature. Researchers propose new descriptive terms that do not have the genetic connotation of "terrace." The subdivisions within the Norfolk study area shown in figure 1-3 and table 1-2 (from west to east) are: Churchland flat, Dismal Swamp, Deep Creek Swale, Fentress Rise, Hickory Scarp, Mr. Pleasant Flat, Oceana Ridge, Sand Ridge and Mud-Flat Complex, and Diamond Springs Scarp (Oaks and Coch, 1973).

All in all, these geomorphic characteristics have offered diversified environmental opportunities for housing, recreation, and water-oriented industrial development. The area, however, is not without problems directly related to its geomorphic character. For example, the capacity of the soils to support urban development and absorb its accumulation of waste varies. Most of the older core urban areas are already served by sewers. Up to the present, the extension of sanitary sewers to nonurban areas has progressed primarily in accordance with demand and available financing. In areas not penetrated by sewer lines, development has been limited by the effectiveness of natural drainage and the suitability of the soil for the use of septic tanks. This problem illustrates one of several geologic factors affecting land use in the area.

Natural Terrestrial and Aquatic Vegetation

The land cover of the Norfolk test site area lies within the transitional zone between broadleaf deciduous and needleleaf vegetation (Kuchler, 1960). The area has a considerable extent of marsh and beach vegetation as well as a variety of submerged aquatic plant communities. Craig (1949) has mapped the major forest types (figure 1-4).

MAJOR MORPHOLOGIC SUBDIVISIONS



Adapted from Oaks and Coch, 1973.

Figure 1-3

Table 1-2--Geomorphic subdivisions within the Norfolk test site

(Adapted from Oaks and Coch, 1973)

Subdivision	Description
Churchland Flat	The Churchland Flat lies north of the Dismal Swamp and its elevation ranges between 18 and 25 ft. (5.5 and 7.6 m). It is underlain by lagoonal-estuarine sediments.
Dismal Swamp	The surface of the Dismal Swamp slopes gently eastward at (.19 m/km) to an elevation of 4.6 m at the Deep Creek swale. Lake Drummond occupies a large oval depression 3.2-4.8 km in diameter in the undissected surface of the swamp. Extremely acidic, freshwater mucky peat underlies the surface to depths of as much as 4 m.
Deep Creek Swale	The land surface of this subdivision rises westward to the Dismal Swamp and eastward to the Fentress Rise, the bottom elevation lies between 3.1 and 4.6 m. Subsurface materials consist primarily of sandy, clayey silt or plastic clay which are former lagoonal and offshore deposits.
Fentress Rise	The Fentress Rise consists of five large remnants of a gently westward-sloping surface that rises eastward from the Deep Creek swale to a flat crest with an elevation between 6.1 and 7.6 m. The remnants are separated by four east-west trending valleys, three of which lie entirely in Virginia and are the eastern and southern branches of the Elizabeth River, and the Northwest River. The fourth remnant continues into North Carolina and can be followed southward as far as Albemarle Sound. Higher parts of the Fentress Rise are underlain by marine sediments.
Diamond Springs Scarp	The Diamond Springs scarp is a distinctive east-west trending feature that forms the north face of the Fentress Rise and of Oceana ridge. The elevation of the crest ranges from 6.1-7.6 m. Beach sand underlies the scarp.

Subdivision	Description
Hickory Scarp	The Hickory scarp forms the eastern boundary of the Fentress rise and the western limit of the Mt. Pleasant flat. It is low and indistinct in the field, yet is apparent on soil maps and aerial photographs. The scarp is underlain by beach and dune sand and gravel.
Mt. Pleasant Flat	The Mt. Pleasant flat forms a broad, generally undissected area 8.1-14.5 km wide, from east to west, and 29-32.2 km long from north to south. The surface lies between 3.1 and 5.2 m but only six areas lie between 4.6 and 5.2 m, which include a subsequent feature and five linear areas. The remaining area is poorly drained and so has been extensively ditched to promote better drainage. Lagoonal and marsh sediments form most of the surface of the flat.
Oceana Ridge	The Oceana ridge is 2.4 km wide and 11.3 km long and trends to the southeast from the Diamond Spring scarp in the north. Its crest is as much as 7.6-9.1 m above sea level. The western slope is only slightly more gentle and less linear than the moderately steep eastern face. The ridge is underlain by beach and dune sand.
Sand Ridge and Mud Flat Complex	The sand ridge and mud flat complex consists of linear ridges of sand and intervening lower lying mud flats situated east of the Mt. Pleasant flat. Much of the area is occupied by the Back Bay lagoon. The complex is underlain by beach sand and lagoon flat sediments (barrier).

Major Forest Types

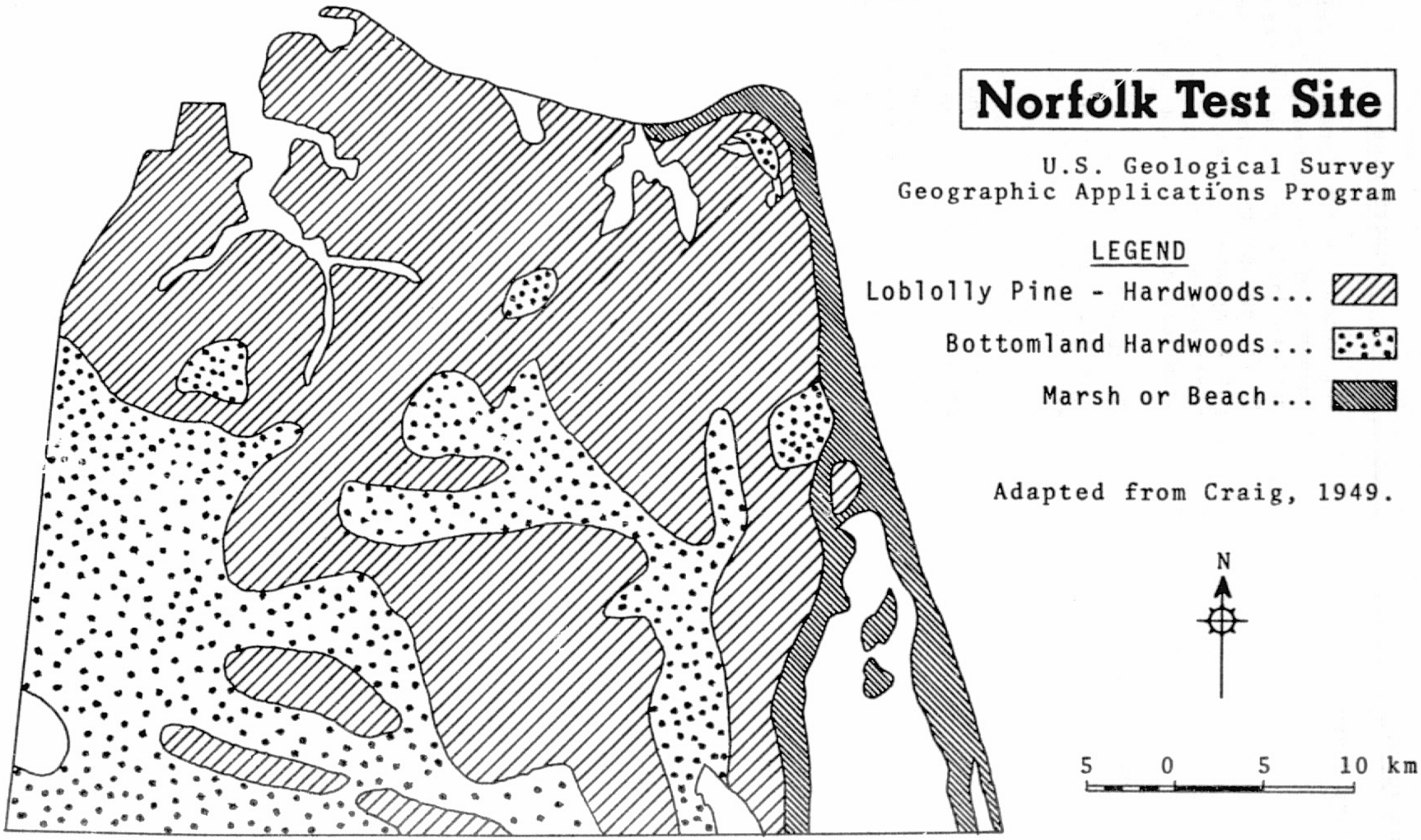


Figure 1-4

Most of the existing forests are a mixture of loblolly pine and hardwoods with underbrush of holly, ferns, blackberry and smilax. Loblolly pine is the most common tree, and in many places even-aged pure stands develop in abandoned fields as well as in well-drained and imperfectly drained sites. Hardwoods associated with loblolly pine on well-drained sites are red oak, white oak, hickory and holly. Hardwoods such as beech, sycamore, sweet gum, black tupelo, yellow poplar, and red maple are found on poorly drained bottomland sites. White cedar, water oak, willow oak, swamp blackgum, and cypress are found in fresh water swamp areas, such as the Dismal Swamp.

Tidal and fresh-water marshes support a dense growth of coarse reedy grasses. Common brackish water species are needle rush, and salt marsh cord grass. Common fresh-water marsh species include cattails, wild rice, and giant cutgrass. Submerged aquatic vegetation likewise varies with salinity values. Marsh grass and eelgrass are common brackish water submerged species, whereas sago pondweed, wild celery, red headgrass, and widgeon grass grow under fresh water conditions.

The plant zonation on barrier beaches or islands is diverse (figure 1-5). Cordgrass and sea oats occur on low natural dunes. The distribution of plants on the overwash terrace behind the natural dunes is a function of the frequency of overwash. The areas of most frequent overwash have a sparse cover of cordgrass and goldenrod. Behind the terraces, dense bulrush can be expected. Where overwash is infrequent shrub thickets of sea myrtle, wax myrtle and marsh elder are the dominant plant species. Live oak, red cedar and yanpon shrub thickets can also

CROSS SECTIONS OF A BARRIER ISLAND (Adapted from Dolan and others, 1973)

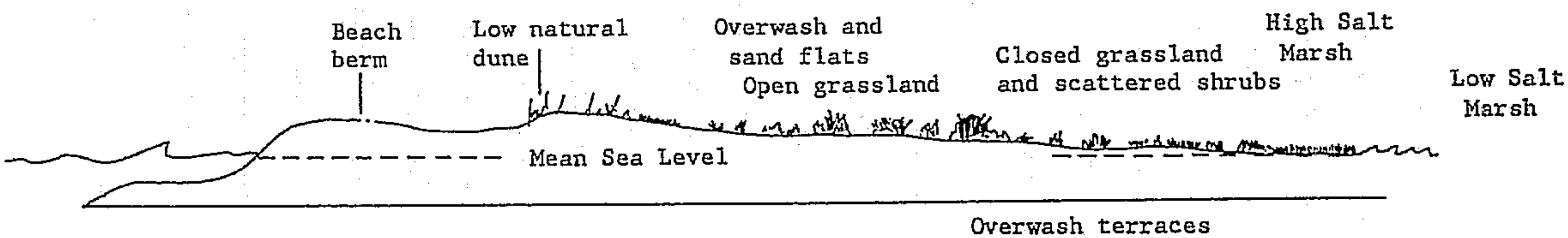


Figure 1-5

occur in this area if sufficiently protected by dunes. Salt marshes border the sound side of the barrier beach of islands. The high salt marsh develops on terraces within reach of the tides and is dominated by black needle rush or cordgrass (Dolan and others, 1973). The effects of changing land use patterns and management practices on the ecology of the natural terrestrial and aquatic vegetation will be discussed in the environmental impact section of this report.

Water Resources

The land area of the Norfolk test site is nearly surrounded by water and it is traversed by numerous rivers and waterways. In fact, 9.2 percent of the total area of the SMSA is water. The cities of Chesapeake, Norfolk, Portsmouth, and Virginia Beach have approximately 2,500, 2,300, 3,600, and 13,900 ha (6,100, 5,700, 8,800, and 34,400 acres) of surface water, respectively. Urban water use pressures are considerable, the large surface water resources notwithstanding.

The surface water resources in the cities of Norfolk, Portsmouth, and Chesapeake are, in a sense, limited. The Elizabeth River and its main branches, which drain the northern portion of the study area into Chesapeake Bay, are tidal. The Northwest River drains a portion of the Dismal Swamp in the southern section of Chesapeake and the North Landing River drains the eastern portion. Lake Drummond, in the Dismal Swamp, lies in the western section of Chesapeake. Water from the swamp drains into the lake and, thence, into a canal which is part of the Intracoastal Waterway.

The city of Norfolk obtains part of its water supply from reservoirs in the eastern part of the city, but increasingly the city has sought water from the Nansemond, Blackwater, and Nottoway Rivers to the west. Portsmouth's water supply is obtained from impoundments on the headwaters of the Nansemond River (Virginia Division of State Planning and Community Affairs, 1973b).

Limited surface water is available for urban use and development in Virginia Beach. The main streams are Little Creek, Lynnhaven Bay and tributaries, North Landing River and West Neck Creek. Back Bay, a considerable expanse of brackish water, consists of approximately 10,900 ha (27,000 acres) of open water and marsh. As a result of this limited supply, water for urban use in Virginia Beach is obtained from the Norfolk water supply system.

In the area as a whole, ground water resources are limited by the problem of saltwater intrusion and the general poor chemical quality of water in deep aquifers. The problem worsens with increasing depth and distance to the east. The development of surface and ground water resources for urban use presents difficult-to-solve problems caused by far-reaching tides, salinity, and very low relief.

Wildlife and Fish Resources

The wetland and estuarine environments in the Norfolk test site area are rich in wildlife and fish resources. These resources are of critical environmental concern because changes in land use policies can have dramatic effects on wildlife and fish habitats and populations.

The study area has two major areas of environmental concern - the Great Dismal Swamp and the Back Bay. The Dismal Swamp, though relatively close to the urban centers of the Norfolk test site, is largely a vast wilderness. Animal species include treefrogs, copperhead snakes, spotted turtles, black bears, bobcats, and white tailed deer. A rich bird fauna in the swamp includes approximately 80 species of breeding birds (Meanley, 1968). Changes in land cover through drainage and forest utilization have had an impact on wildlife in the swamp.

The Back Bay wetland and estuarine environment is rich in fish and waterfowl species (table 1-3). The size and diversity of the fish population is a function of water salinity and turbidity. The size of the waterfowl population is influenced by the quantity and diversity of the aquatic vegetation as well as the availability of farm crops in the area. The quantity of aquatic vegetation can be reduced as a result of an increase in water turbidity caused by sedimentation from urban construction. Interpretation of wildlife and fish resource problems in the Back Bay as related to land use change will also be examined later in this report.

Population and the Growth of Political Jurisdictions

The development of local political jurisdictions from the late 19th Century to the present in Southeast Virginia has been influenced by the unique practice of city-county separation in Virginia, the wide-spread practice of annexation of county land by cities, and the resulting territorial competition among local political entities. Until recently, when a Virginia town attained a population of 5,000, it could become a city, at which time it assumed most county functions. Upon gaining a population of

Table 1-3--Common species of fish and waterfowl found in Back Bay

(U.S. Bureau of Sport Fisheries and Wildlife, 1966)

FISH SPECIES	WATERFOWL SPECIES
(Fresh Water)	
American eel	American Goldeneye
Black Bullhead	Baldpate
Black Crappie	Black Duck
Bluegill	Bufflehead
Blue Spotted Sunfish	Canvasback
Bowfin	Canada Geese
Carp	Coot
Channel Catfish	Gadwall
Chain Pickeral	Mallard
Eastern Banded Killifish	Pintail
Golden Shiner	Redhead
Largemouth Black Bass	Ring-necked Duck
Longmore Gar	Ruddy Duck
Pumkinseed	Scaup
Redfin Pickeral	Shoveler
White Catfish	Snow Geese
Yellow Bullhead	Teal
Yellow Perch	Whistling Swan
	Wood Duck
(Salt-Brackish Water)	
Alewife	
American Shad	
Atlantic Needlefish	
Atlantic Silversides	
Flounder	
Gizzard Shad	
Manhaden	
Rough Silversides	
Striped Bass	
Striped Mullet	
White Perch	

10,000, a city could obtain total independence from the county of which it was a part. Upon establishing justification in court, any city, under Virginia annexation law, may annex land from adjacent counties.

Under the system commonly used in the United States, in which the city is actually a part of the county, annexation results in no loss to the county or territory, population, or tax base. In Virginia, however, with county-city separation, annexation does result in such losses. Although the county losing territory is compensated by the city, liberal annexation laws have resulted in often bitter rivalry among cities, strong county resistance to annexation, and the formation of cities from counties that are primarily rural.

Norfolk was founded in 1682 and developed into an important seaport. Across the Elizabeth River from Norfolk, Portsmouth was founded in 1752 as a rival port town, and in 1858 became an independent city with a population of 9,000. The remainder of the present day Norfolk-Portsmouth SMSA consisted of Norfolk County, to the north, south, and west of the cities and Princess Anne County to the east and south.

The growth of the area's population has reflected the expanding involvement of the American military and the growth of the U.S. Naval facilities in the Hampton Roads area. As the population has expanded beyond the city limits, the political response has been annexation of land or the formation of new cities. The city of Norfolk annexed Norfolk County territory in 1906, 1911, 1923, and 1955. In 1921, the city of South Norfolk was created from part of Norfolk County, and it annexed additional territory in 1951. East of Norfolk, Virginia Beach, Princess Anne County's largest town, became an independent city in 1952. By the early 1950's, the cities of the Norfolk-Portsmouth region were all competing for additional county land. Norfolk and Princess Anne Counties, on the other hand, exerted great effort in resisting further territorial erosion by annexation.

In 1953, Portsmouth filed suit to annex 64.8 km^2 (25 mi^2) of Norfolk County, including suburbs and vacant land south of the city, but not until 1960 was Portsmouth awarded 25.9 km^2 (10 mi^2) with a population of 36,000. Portsmouth again tried to annex Norfolk County territory in 1961. But Norfolk County and South Norfolk, a small industrial city which feared encirclement by Portsmouth and for financial reasons had not been engaged in annexation, merged to prevent further annexation. The merger in 1963 created the city of Chesapeake. This new city challenged the right of Portsmouth to annex further territory, but, under the merger provisions, the annexation suit was kept alive. By 1968, Portsmouth was awarded another 25.9 km^2 (10 mi^2) and 36.3 km^2 (14 mi^2) of water northwest of the city. Also in 1963 Virginia Beach merged with the remainder of Princess Anne County to form a larger Virginia Beach (Eyre, 1970).

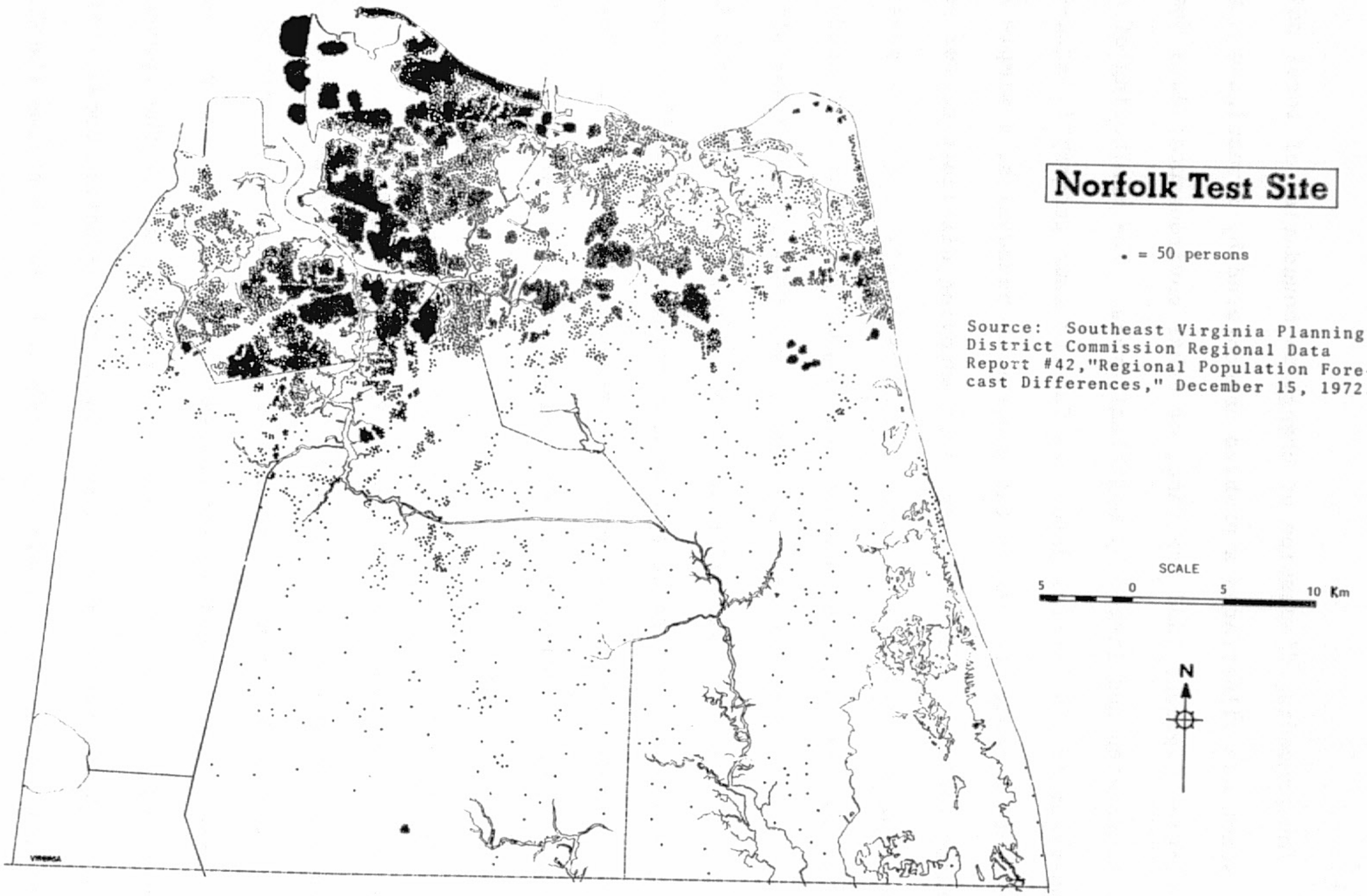
By 1968, the Norfolk-Portsmouth SMSA was entirely composed of incorporated cities, and any further annexation would have to occur to the west in Nansemond County. A merger between the city of Suffolk and Nansemond County, effective on January 1, 1974, brought an end to annexation possibilities for cities within the 1970 Norfolk SMSA.

City territorial expansion is now limited to city mergers, use of filled areas and the potential for purchasing military-owned land declared surplus.

The preceding discussion of change in boundaries of local political jurisdictions illustrates a problem encountered by investigators wherever population figures, land use data, or other environmental data summaries are aggregated and listed by political areas. The monitoring of change--comparison of time series data sets for the same geographic area--must take into account changes in the geographic boundaries, a simple and self-evident fact, but one which can cause annoying difficulties for compiling and using area statistics. The problem is likely to be more severe where change is most rapid; even within the 3-year period of this study, a change occurred in the area included in the SMSA of which Norfolk is a part. This kind of situation is one additional reason for adopting a geographic-based reference system illustrated by the CARETS project, wherein environmental data carry reference to location on the Earth's surface, and according to any desired county, regional planning district, or other areal unit.

The growth of political areas within the Norfolk test site reflects the population growth of the area. Figure 1-6 displays the population distribution within the area; the highest population densities naturally occur within the urbanized areas in the north-central portion of the SMSA, the urban cores of Norfolk and Portsmouth, along the eastern, western, and southern branches of the Elizabeth River, and near the Chesapeake Bay. Table 1-4, listing the area, population, and population density of the test site and its component cities from 1960 and 1970, confirms the information

POPULATION DISTRIBUTION, 1970



U.S. GEOLOGICAL SURVEY

GEOGRAPHY PROGRAM

Figure 1-6

Table 1-4--Population densities of Norfolk test site

Population	Chesapeake	Norfolk	Portsmouth	Virginia Beach	Norfolk test site
1960	66,247	304,869	122,173	85,218	578,507
1965	81,441	314,189	127,000	142,670	665,300
1968	89,111	315,621	128,622	171,039	704,393
1970	89,580	307,951	110,963	172,106	680,600
Land Area (excluding water and marsh)					
Square miles	328.1	53.6	30.2	226.9	638.8
Hectares	84,977.9	13,882.4	7,821.8	58,767.1	165,449.2
Density (persons/mi^2)					
1960	202	5,688	4,045	376	906
1965	248	5,862	4,205	629	1,041
1968	272	5,888	4,259	754	1,103
1970	273	5,745	3,674	758	1,065
Persons/Hectare					
1960	.78	22.0	15.6	1.5	3.5
1965	.96	22.6	16.2	2.4	4.0
1968	1.05	22.7	16.4	2.9	4.3
1970	1.05	22.2	14.2	2.9	4.1

Source: Southeastern Virginia Planning District Commission, 1972.

provided by the population density map. Norfolk is by far the most densely populated city, with a dense population throughout excepting the northwest military and transportation facilities and several commercial and industrial islands. Portsmouth, the smallest municipality in the study area, has a somewhat lower density, due in part to recently annexed open and forest land. Virginia Beach is most heavily populated in its northern third, particularly in its ocean resort community, whereas its southern two thirds, consisting of much of the former Princess Anne County, is sparsely populated and rural. The city of Chesapeake has the lowest population density, with a large part of its area in farms, forest and the Dismal Swamp. As one might expect, its highest population density occurs in the Borough of South Norfolk, formerly a separate city along the southern branch of the Elizabeth River, and near the Portsmouth city line. The heavily populated area north of the Western Branch and now a part of Portsmouth was the area of Chesapeake annexed in 1968. As in Virginia Beach, southern Chesapeake is very thinly settled.

The population of the Norfolk test site is and has been a highly transient one, heavily dependent upon government employment, primarily military and civilian at area naval bases. Such employment in 1971 provided 53.3 percent of personal earnings for the area (Southeastern Virginia Planning District Commission, 1973). The predominance of government employment in the region indicates that the region's growth will be heavily influenced by government operations. Table 1-5 presents population projections up to 1990 for the region and its component cities and the percentage of estimated population change. Chesapeake is projected to be

Table 1-5--Population forecasts for the Norfolk test site*

	Chesapeake	Norfolk	Portsmouth	Virginia Beach	Total
Census 1960	66,247	304,869	122,173	85,218	578,507
Percent Change 1960-70	35.2	1.0	(-) 9.2	102.0	17.6
Census 1970	89,580	307,951	110,963	172,106	680,600
Percent Change 1970-80	26.6	(-) 3.4	26.3	71.2	24.2
Projections 1980	113,400	297,400	140,100	294,600	845,500
Percent Change 1980-90	44.7	1.9	7.6	29.9	18.3
Projections 1990	164,100	303,000	150,700	382,600	1,000,400

*1960 Population: Bureau of the Census, adjusted for 1968 Churchland annexation from Chesapeake to Portsmouth
1970 Population: Bureau of the Census. From forecasts by the Southeast Virginia Planning District Commission, 1972.

the fastest growing city, followed by Virginia Beach, Portsmouth, and Norfolk by order of the amount of undeveloped land within each jurisdiction. Extensive population growth is expected to occur in the center of the presently densely populated areas and in a few areas peripheral to the present populated centers. Little growth is expected to occur, however, in the predominantly rural areas of the southern half of the region.

Major Land Uses

The Norfolk-Portsmouth area's coastal location accompanied by its temperate climate has made it a prime site for the concentration of military installations as well as commercial, agricultural, and recreational land use. Military, particularly naval, bases hold large blocks of land in the area comprising over 8,910 ha (22,000 acres) of the test site or 28 percent of the total. The armed forces and civilians who work at military installations comprise 33.6 percent of the area's total employment (Southeastern Virginia Planning District Commission, 1973).

Certain commercial activities have also been encouraged by coastal locational factors. This area is one of the most important coal handling ports in the world and one of the major ports of exportation in the United States. CARETS land use data for 1970 indicate that commercial and industrial land accounted for only 3.1 percent of the total land use. Commerce and industry, however, accounted for almost 42 percent of personal earnings in the test site.

Location, climate, and natural resources have encouraged recreational land use in the area. The test site has over 48 km (30 mi) of ocean frontage as well as Chesapeake Bay frontage and miles of waterways for swimming, boating and fishing. The city of Virginia Beach has the 1,134 ha (2,800 acres) Seashore State Park, which is preserved as a natural area. The Back Bay National Wildlife Refuge is also in Virginia Beach and provides opportunities for waterfowl hunting and fishing as well as for nature studies. In Chesapeake, 19,848 ha (49,000 acres) of the Dismal Swamp have been set aside as a national wildlife refuge. These varied recreational land uses are under increasing pressure as demonstrated by the increase in the number of visits to the Back Bay Refuge, from 10,000 in 1960 to 235,000 in 1970 to 350,000 in 1971 (U.S. Bureau of Sport Fisheries and Wildlife, 1972).

A fourth major land use encouraged by the location and climate is agriculture and, to a lesser extent, forestry. The long frost-free season and close markets have encouraged vegetable farming and intensive farming. Both agriculture and forest land use are predominately restricted to the cities of Chesapeake and Virginia Beach. They are important economically and from an areal standpoint, although they employ only a small proportion of the population.

Land use in the Norfolk test site is thus a mosaic of urban, agriculture, forest, nonforested wetland, and water uses. The land situation in the area is not only one of intense use, but also of competing uses. Residential, commercial, institutional, industrial, and extractive land uses compete with agriculture, forest, nonforested wetlands, and natural estuarine systems for the use and maintenance of the area's land and water resources. The most aggressive elements in the competition for land are residential and commercial-recreational developments and the institutional, commercial, and transportation facilities required to serve them. The uses in retreat are agriculture, forest, and ecological reserves on public lands.

The Norfolk test site, then, is in a dynamic state of intense land use and land use competition. This report presents an interpretative analysis of land use patterns and change trends derived from CARETS land use data sets. The environmental impact of changes in land is also examined.

CHAPTER 2

LAND USE INTERPRETATION AND COMPILATION PROCEDURES

INTRODUCTION

Chapter 2 presents the procedures used by the CARETS program to compile, map, verify, and determine the accuracy of land use data from high-altitude aircraft photography and LANDSAT imagery. A detailed statement is included of all the major procedures involved, including techniques used in the detection of land use change.

The land use data derived from high-altitude aircraft photography and LANDSAT imagery form the principal component of the CARETS land use information system. The approach of the CARETS experiment to test the value of LANDSAT imagery as a source of land use information was to map the region first using high-altitude aircraft photography to provide a standard for comparison of the LANDSAT-derived data. Table 2-1 presents a comparison of area summaries for Level I land use (excluding water bodies) between high-altitude aircraft photography and LANDSAT-derived land use data for 1972. CARETS investigators obtained the 1972 aircraft data by adjusting the 1970 land use data with that obtained from 1970-72 change detection work. This chapter presents discussions of the data used in compiling table 2-1, along with reasons for differences in land use classification based on aircraft and LANDSAT data.

Table 2-1--Comparison of 1972 aircraft* and LANDSAT** Level I land use areas*** for the Norfolk test site

LAND USE	1972 AREA FROM AIRCRAFT DATA INTERPRETATION		1972 AREA FROM LANDSAT DATA INTERPRETATION	
	Hectares	Acres	Hectares	Acres
URBAN	43,102	106,505	47,736	117,956
AGRICULTURE	48,391	119,574	48,047	118,724
FOREST	75,475	186,499	75,136	185,661
NONFORESTED WETLANDS	7,802	19,279	5,444	13,452
BARREN	1,434	3,543	1,448	3,578
TOTAL	176,204	435,400	177,811	439,371

*Source: 1970 CARETS aircraft data area measurements digitized by the Canada Geographic Information System (CGIS) adjusted for 1970-72 Level I change

**Source: 1972 CARETS LANDSAT data area measurements from maps digitized by the CGIS

***Does not include category 5, water bodies

INTERPRETATION AND COMPILATION FROM HIGH-ALTITUDE PHOTOGRAPHY

The initial land use mapping effort required source photography providing greater detail than LANDSAT imagery and also suitable for constructing a rectified gridded mosaic mapping base. Available photography at or near the desired scale of 1:100,000 included 1970 and 1971 coverage of most of the CARETS region by NASA missions 144 and 166, over NASA Test Site 244. This photography was of additional value because the land use maps compiled from it could be correlated with 1970 census data.

Mission 144 was flown by an RB-57 aircraft at an altitude of 60,000 feet on September 22-25, 1970, and Mission 166 was flown on May 19, 1971. The outer limits of the photo coverage approximated CARETS regional boundaries.

NASA assembled an array of sensors for use with high-altitude aircraft, including two Wild-Heerbrugg 9-inch format cameras with 6-inch focal length lenses, and six 70-mm format Hassleblad 500 EL cameras 40-mm focal length lenses. The transparencies used as source material for interpretation were reproduced from the original 9-inch format RC-8, 2445 Eastman Kodak Ektachrome Color Aerial film. Color infrared film produces a "false color" effect, in which healthy vegetation appears red rather than green.

The 1:120,000-scale Mission 144 and 166 RC-8 coverage was used in constructing 1:100,000 controlled mosaics. On the RC-8 transparencies, some features as small as 15 feet in length could be identified. The equivalent figures for the other photographic systems were 10-15 feet for the Zeiss and 42-45 feet for the Hassleblad cameras. The RC-8 color infrared transparencies also provided relatively sharp detail, freedom from haze, and very good color balance. Cloud cover problems affected only a small portion of the total area.

The Mosaic Base

The 1:120,000-scale RC-8 coverage was used in constructing photomosaic mapping bases. Prepared by the Topographic Division of the U.S. Geological Survey, these mosaics were constructed on rectified black and white stable base film positives and used to key regional data sets to precise locations on the surface of the Earth. The 1:100,000-scale photomosaics were overlaid with a 1-km^2 grid measuring 50 km on a side and keyed to the coordinates of UTM zone 18. Geographic tick marks at 5-minute intervals were also added to the mosaics as additional locational references.

Limited testing for cartographic accuracy of these mosaics revealed that 90 percent of the well-defined points were estimated to within 1 mm (.04 inches) of their true positions. At a scale of 1:100,000, 1 mm represents 100 m on the ground. This error is twice that permitted by U.S. National Map Accuracy Standards. Because these mosaics were not intended to be final products, but rather a step in the mapping process, they lack the careful tonal matching from print to print that is characteristic of USGS published mosaics.

Land use was compiled on frosted acetate drafting film overlays, registered to the mosaics using the USGS standard punch format and registration pins. In addition, grid-intersection tick marks and labels were placed at the four grid corners on each overlay. An index to the CARETS mosaic, land use and related data base sheets is presented in figure 2-1.

Interpretation

The initial interpretation of CARETS was performed using an eight-power monocular hand lens to view the film transparency on a light table. The interpreter identified land use on the photography, marked the land use boundaries on the drafting film over the corresponding land use area on the mosaic and then marked the two-digit land use identifying number within the polygon.

Because many land uses visible on the photography are quite small and difficult to record, a minimum recording size of 2 mm (200 m on the ground) was established. Any land use areas with dimensions smaller than 2 mm were not recorded, but rather incorporated into surrounding or neighboring polygons. This practice eliminates many important landscape features such as roads, streets, and streams that are too narrow to record.

Besides using color and color infrared photography, the interpreters also used city, county, and State road maps, regional and planning district maps and 1:24,000 and 1:250,000 series USGS topographic sheets as supplementary sources of information to aid in identification.

Upon completion of land use mapping, the manuscript maps underwent an editing process involving two procedures: the systematic study of the entire mapped area of each sheet and a careful matching of the unconnected line segments on each side of adjoining sheet margins.

INDEX TO AIRCRAFT COMPILED, 1970 LAND USE MAPS

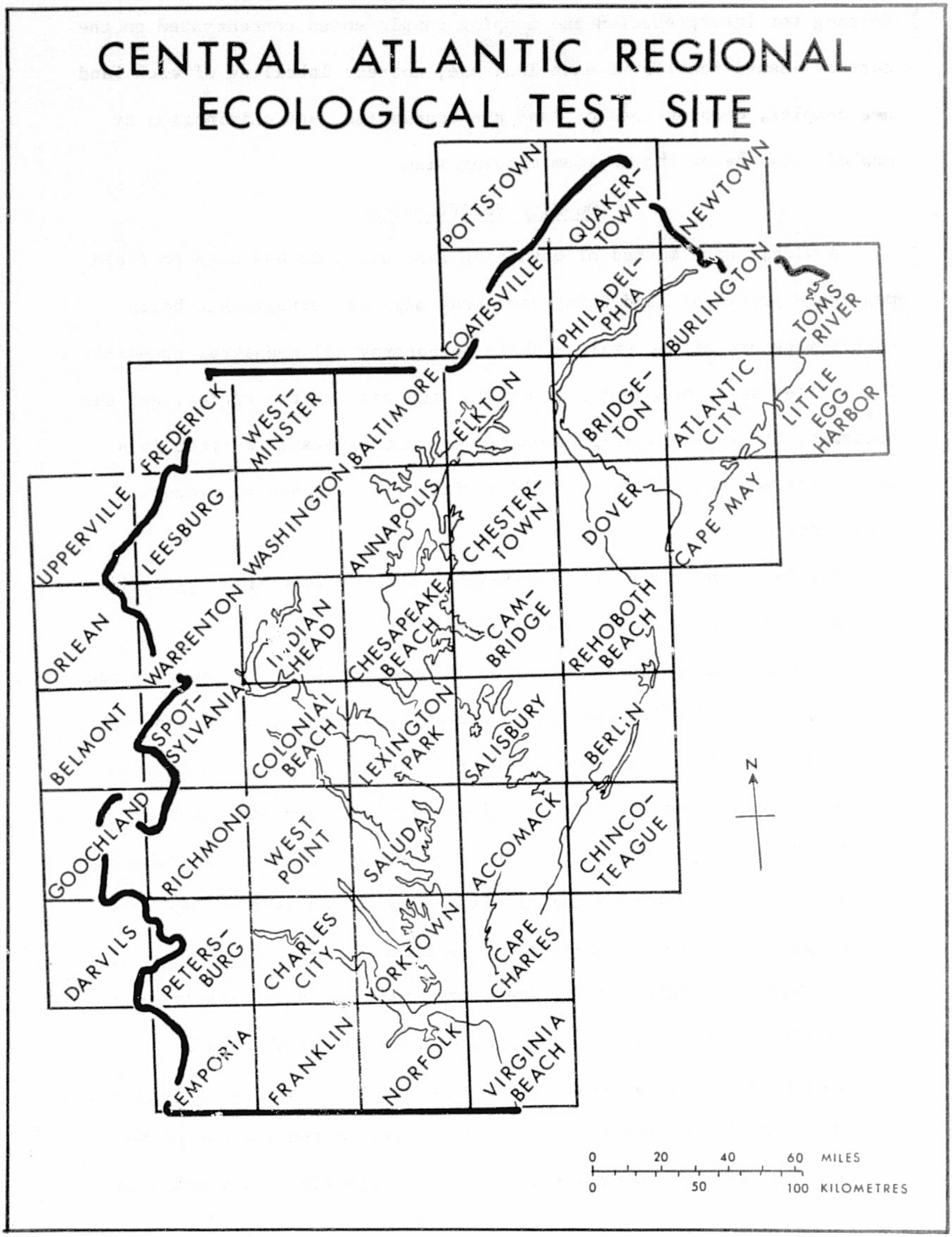


Figure 2-1

Editing for interpretation and mapping completeness concentrated on the correct identification of each land use, correct labelling of each land use complex, completeness of land use boundaries, and elimination of mapped areas below the minimum mapping size.

On-Site Verification

A widely used method of obtaining land use data has been to field map every parcel of land using cadastral maps as cartographic bases. CARETS maps are at too small a scale to portray all cadastral boundaries. The smaller scale of mapping in CARETS, the size of the region, and the necessity for rapid mapping to obtain current coverage resulted in a search for new techniques of field verification and new map accuracy standards.

The following goals were established for the initial on-site field verification of the CARETS land use maps:

1) Areas and point features that proved difficult to identify and classify in the interpretation process would be examined thoroughly in the field to complete the identification of questionable areas and resolve classification problems that had been encountered.

2) Sampling procedures designed to examine the error from whatever source--interpretation and classification to manuscript map preparation--would be tested in the field.

3) Specific classification-category areas would be investigated to discover the "mix" of noncategory land uses within each designated category area, in order to determine the percentage of error resulting from both interpretive errors and the use of the minimum-area recording unit as a tool of discriminatory analysis.

Based on these goals, procedures for a limited on-site field verification experiment were designed and tested by members of the Geographic Applications Program staff. The results of that experiment conducted during 1972 in the portion of the CARETS region south of Richmond, Virginia, indicated that the procedures could, to a significant degree, satisfy these objectives. The field activities in this experiment involved three basic phases: (1) preliminary planning, (2) on-site investigation, and (3) data analysis.

The preliminary planning stage included acquiring necessary support materials (manuscript maps supported by road maps, planning commission maps, and 1:24,000-scale USGS topographic sheets) and determining the areas to be checked. The following types of features were identified for examination, noted on the manuscript maps for location, and outlined on topographic and road maps:

1) Special feature areas.--These included land use areas identifiable only in the field or possessing unique characteristics presenting classification difficulties. This category also included sites for which photographs and further observation were desirable.

2) Category areas.--Sample areas of a three-to-five city block size were selected within the Level II land use boundaries for each category recorded. These areas were to be observed to discover the percentage "mix" of noncategory features within each category area. They were usually selected from the central portion of each category area to avoid the mixture problems associated with boundaries on the fringes.

(3) Boundary areas.--Sample areas of a similar size to the category areas were designated along various sections of Level II land use boundaries for examination of the "mix" in those areas and also for verification of boundary correctness. Boundary areas, unlike category areas, were divided into equal area sections on each side of the boundary line to provide percentage figures that would also reflect the composition of the fringe areas of the examined categories.

(4) Air observation areas.--These areas were designated for verification by low-altitude aircraft flights because of their relative inaccessability by other means. Their identities could be verified most efficiently by air in terms of both time and travel costs. Air observation areas could include any of the preceding three types of area in theory, although in practice it would be difficult to map the more complex category and boundary areas by this method.

Because of time limitations, the goal of the selection process for areas to be examined was to obtain a maximum amount of information with a minimum number of site visits. All accessible special features would be visited, whereas category areas were selected to obtain a sample of a wide range of types, e.g. residential category areas were visited in many different economic classes of neighborhoods. Each category area was selected from the core of the land use polygon it represented, and some category areas were selected because they were located in areas believed to be difficult to classify. Boundary areas were selected in a similar fashion. Air observation areas, with the exception of those special features observed on a brief experimental flight over Norfolk in August, 1971, were left for some future experiment.

Because random site selection procedures were not used, the field results probably contain considerable statistical bias. It is believed, however, that the careful selection of known sites, with a limited range of characteristics, on the basis of previously acquired knowledge about the geographic nature of the area concerned, rendered the sample sufficiently typical to make the figures obtained significant descriptors of the interpretation and mapping accuracy for that part of the CARETS region.

Field observation teams consisted of a driver (who also took photographs and notes on the sites) and a navigator who recorded the pertinent data relating to a site. Special feature, category, and boundary observations were accomplished by driving to and around a designated area, identifying it, photographing (if desired) and field mapping its land use to scale in a notebook, using the two-digit Level II land use code.

The 1971 experiment in air observation proved that observing sites from a low-altitude aircraft can be accomplished in a similar manner, providing the route is carefully planned. It was also found that observations from low-altitude aircraft were much more efficient than those from the ground.

The data analysis phase consisted of measuring land use areas with a dot planimeter on the scale drawings completed in the field; calculating the percentages of the land use mix for each site observed;

reassembling that data into order by categories of the classification system; tabulating, weighting, and averaging the percentage data; and completing identification of special areas by entering the correct notation on the manuscript map.

The most common errors include those of interpretation and judgment (classification errors), boundary placement, incorrect labelling, those resulting from the existence of multiple uses on any one piece of land, and those caused by the time lapse between the date of photography and the date of field verification. The sampling was designed to examine areas (not points) and analyze the working efficiency of individual categories in the classification system on the basis of the percentage mix of category and noncategory use found in the sample areas and the correctness of the boundaries drawn between individual land uses. Though sampling based on areas requires greater effort than that based on points, the findings provide considerably more information relating to the performance of the classification system, the interpreters, and the cartographers.

Three distinct steps have been devised in approaching the question of the accuracy of sample areas: determining the percentage mix of each land use category polygon; establishing threshold limits or amounts of mixing allowable to determine the correctness of polygon interpretation; and summarizing the data, comparing them with established threshold values and obtaining an accuracy statement. Determining the percentage mix of each polygon is accomplished by measurement of the area in the sample polygon and computing the percentage of the total area occupied.

By summarizing the information for all such polygons, according to the categories of land use assigned in the interpretation and mapping processes, and placing the summary percentage data in matrix format, statistics are obtained that can be used in analyzing the performance of each category of the classification system.

By further ordering the percentage mix data, it is possible to obtain figures that can be interpreted as "accuracy" statements in much the same manner as the conventional dichotomous-sampling figures. A percentage threshold may be established to determine what values are acceptable.

The CARETS field verification teams examined and recorded a total of 371 areas during the intitial experiment. Two teams, travelling by automobile, examined and mapped 83 special features, 198 category areas, and 90 boundary areas during 8 days of field work. All accessible sites were mapped; only seven areas were found to be inaccessible. Familiarity with procedures, planned driving routes, and the availability of notebooks with all areas mapped to scale in chronological order led to an average site-mapping time of 2 minutes and an average driving time between sites of 13 minutes.

The general results of the field observations, in the form of percentage-mix matrices, are summarized in tables 2-2 and 2-3. In table 2-2, category areas are examined with respect to their actual percentage mix of both category and noncategory features as observed in the field. The photo-interpreted categories are listed on the left; the field observations are reported in the matrix to the right, according to the percentages of the sample area found to contain the land

Table 2-2--Percentage of actual land use occupying mapped land use categories

Mapped Land Use Category*	Sample Size	Actual Land Use																				
		11	12	13	14	15	16	17	18	19	21	22	41	42	51	52	53	54	61	62	72	74
11	32	89.3	2.1			0.2	0.2			3.0			1.5	3.7								
12	29	13.7	64.4	5.5			7.0		7.0	1.8			0.6									
13	12	0.6	3.0	90.0						6.4												
14	5				72.0					20.0											8.0	
15	14	1.9	1.5			77.1				7.1			5.2	7.2								
16	18	4.4	0.4				91.2	2.2		0.4												1.4
17	4							100														
19	12	5.0	2.5				0.7			86.0	5.8											
21	21	0.1					0.6				79.4		5.8	14.3								
22	2	1.5					1.5					47.0	50.0									
41	14	14.6				1.1				3.6			78.9								1.8	
42	10	1.0								3.0	10.0		4.0	82.0								
52	2															50.0	50.0					
53	6																100					
54	3																	93.3	6.7			
61	9												6.1	1.1	1.7				85.6	5.5		
62	1																			85.0		15.0
72	4	16.3																			83.7	

*(Land use categories key in appendix A)

Table 2-3--Percentage of actual land use occupying land use boundary areas

		Actual Land Use										
Category Number*	Sample Size	11	12	13	14	15	16	19	21	41	42	61
11	71	83.2	7.6				2.4	3.2	1.4	2.0	0.2	
12	37	26.1	56.7	7.9			3.1	5.1	0.3	0.8		
13	16	9.1	20.3	58.3			1.1	9.7		1.5		
14	2				100							
15	6			11.7		88.3						
16	19	1.3					93.9	1.8		3.0		
19	10	6.0						93.3		.7		
21	10						3.5		94.8	1.7		
41	7	13.6	5.0				1.0	4.0		76.5		
42	2										100	
61	3											100

*Land use categories key in appendix A

uses listed along the top of the matrix (land-use category numbers are those listed in the CARETS working version of the land use classification system for use with remote-sensor data). A high percentage figure for matching categories in the table is an indication of few errors in interpretation or mapping. Category 13 (industrial land), for example, presented few interpretation problems according to the modified working version of the USGS classification system. Ninety percent of the land in the designated sample industrial areas contained industrial land use, with insignificantly small amounts of residential, commercial and urban uses. The percentage for matching categories indicates that individual results for each sample area should be checked thoroughly to determine the cause of the error, whether of poor land use category definition, interpreter error, or error in mapping. Both the organization and interpretation of table 2-3 are similar to those of table 2-2, except that the percentages are recorded separately for each of the two halves of the boundary area, as each may be treated as a category area. Thus, a boundary area between categories 12 and 13 would be recorded in the same manner as one category 12 and one category 13 area would be in table 2-2 under the separate headings for each category. The total recorded sample sizes are thus twice as large as the number of boundary areas visited. In this manner, information concerning the composition of the fringe sections of the category areas could be obtained and compared with similar format information from the core of the category areas.

Many of the same problems reappeared in the boundary area matrix presented in table 2-3. A noticeable difference between the two tables, however, was that the percentages for the noncategory areas appeared to be larger in the boundary areas than in the corresponding category core areas. This difference was to be expected in view of the merging that normally takes place in contact zones between concentrations of land use types. Readily apparent in analyzing the causes of the anomalies was the relation between the extreme difficulties in delimiting commercial/residential and commercial/industrial zones and the problems examined above under the table 2-2 discussion. The other apparent anomalies were all due to single and unique interpretation mistakes.

Another type of statistic gathered from the field-mapping notebooks does not appear in the tables: a test, based on the scale drawings, made to determine the boundary correctness for each boundary area visited. For the 92 boundary areas observed, the boundary from the aerial photos had been interpreted correctly in 57 cases (62 percent of the time). In 15 cases (16 percent of the time), minor boundary corrections should have been made; and in 20 cases (22 percent of the time) the boundaries were totally incorrect. The error ratios may be somewhat misleading, as many of the boundary areas were selected from positions that were difficult to interpret to allow scrutiny of particular classification problems. In addition, the sampling procedures were not randomized, and at least some of the boundary errors resulted from incorrect category classifications. Nevertheless, these statistics show that 78 percent of the boundaries were where they should have been.

Finally, the percentage-mix statistics were further analyzed to provide the kind of information required to make accuracy statements on the basis of threshold values introduced to dichotomize the data. The data were repetitively analyzed for threshold values of 100 percent, 90 percent, 67 percent and anything greater than 0 percent; the results of this analysis appear in table 2-4 for category areas and table 2-5 for boundary areas.

The formulation of these statistics was quite simple. When the sample area contained a greater percentage of correctly interpreted land use than the threshold value, the interpretation of the sample area was considered to be correct, and it was thus considered in the determination of accuracy on a hit-or-miss basis. With a threshold value of 67 percent, 29 of the 32 category 11 (residential) areas observed were found to be interpreted correctly, for a 90 percent "accuracy" statistic. Averages of these percentages, adjusted for the sample size, were also computed for each threshold value, and appear at the bottom of the appropriate columns.

Two conclusions can be drawn from these tables: (1) no matter what the threshold value, boundary areas appeared to be more difficult to interpret than category areas and more rigorous threshold values tend to cause poorer accuracy statistics; and (2) field verification results presented in this format are so far removed from the original data that it is impossible to use them for analytical purposes in the fashion that the percentage-mix figures were used.

Table 2-4--Category area accuracy analyses

Category	Sample size	Correct sample percentages observed according to the following threshold values: Any %	67%	90%	100%
11	32	100	90	68	63
12	29	79	59	52	45
13	12	92	92	83	83
14	5	80	80	40	40
15	14	93	79	71	64
16	18	100	89	78	72
17	4	100	100	100	100
18	12	92	92	75	65
21	21	81	81	72	67
22	2	50	50	50	0
41	14	86	79	64	64
42	10	90	80	80	70
52	2	50	50	50	50
53	6	100	100	100	100
54	3	100	100	67	67
61	9	100	78	67	44
62	1	100	100	0	0
74	4	100	75	75	75
Adjusted percentage averages		91	81	69	63

Table 2-5--Boundary area accuracy analyses

Category	Sample Size	Correct-Sample Percentage Observed According to the Following Threshold Values			
		Any %	67%	90%	100%
11	71	93	82	70	63
12	37	81	49	38	27
13	16	81	56	50	31
14	2	100	100	100	100
15	6	100	83	83	83
16	19	100	95	84	79
19	10	100	90	90	80
21	10	100	90	80	80
41	7	100	87	57	43
42	2	100	100	100	100
61	3	100	100	100	100
Adjusted Percentage Averages		92	76	66	58

Analysis of the Field-Verification Data

In the field, 198 category areas were visited, and sites were observed for all 18 of the categories found to be present in this section of the CARETS region. The statistics in table 2-2 reveal the type of category and noncategory mixing resulting from the use of the minimum-area recording unit and the problems introduced by the other sources of error. The appearance of anomalies in this table, in the form of high percentages of noncategory areas present within a particular category, indicate either a weakness in the classification system or an error in interpretation and mapping. Where apparent problems existed, the original field notebooks were checked thoroughly to determine an explanation. By analyzing the data in this manner, it was possible to identify several problem areas. The large mixture of categories present in commercial areas (12) suggests that more use should be made of the urban mixed category (18) or that the commercial and services category should be redefined. A large amount of open land (19) is found in transportation areas (15), especially at freeway intersections, and it is difficult to sort out residential areas (11) from forestland (41) in which many houses have been constructed. In addition, the field investigation revealed that some of the category area problems could be resolved only by persistent field visits. Many "industrial parks" are primarily commercial (12) and not industrial in nature, and open land and extractive scars must frequently be directly observed to ensure proper identification, as between areas "under-construction" and operating sand or gravel pits. The reader may draw his own conclusions concerning the usability of the statistics that have been presented.

Aerial Photography Change Detection

The accurate detection of change from high-altitude aircraft photography involves a very tedious process that is some respects is still in a developmental state. Because of the large size of the Central Atlantic region and the limited time available, the change detection of CARETS has suffered. Although CARETS change detection work has not been field checked, a comparison of an intensive change detection experiment using LANDSAT imagery and high-altitude aircraft photography in the Norfolk area (the results of which will be presented later) with that conducted for Norfolk as part of CARETS using only high-altitude aircraft photography, reveals that considerably less change in the latter was detected.

The method of detecting land use change for CARETS consisted primarily of comparing for changes the 1972 photography of an area with the 1970 photomosaic of the same area overlaid by the 1970 land use map. This method may be useful for rural areas where changes are few and obvious, but it appears to be insufficient for urban or dynamic areas where change is great and may be subtle.

Because of these problems, this report will summarize the land use detection procedures for urbanized areas developed by the USGS Geographic Applications Program's Census Cities project as it would apply to CARETS land use change between 1970 and 1972. Although highly time consuming, these procedures appear to comprise the most accurate manual method and are particularly apt for detecting land use changes in urban areas.

Before conducting a change detection study, necessary photography and materials must be prepared. Photography for the two different time periods is required along with the photomosaic mapping bases and land use transparencies covering the area to be examined. Also necessary are 1-km^2 grid templates on positives film transparencies at the same scale as the photography (1:120,000), the grid of which serves as the basic unit of observation, enabling a block by block comparison.

The 1-km^2 grids are positioned on the 1970 and 1972 film transparencies so that two or more grid cells enclose an area common to that enclosed by grid cells on the 1970 mosaic. Then using a hand lens, the interpreter compares areas of land use within each grid cell. The land use overlays are first checked with the 1970 photography to insure agreement. Then valid changes in land use categories are identified by superposition of photography (1970 over 1972) if scales are similar or juxtaposition otherwise.

When making change assessments, several types of change are identified:

1) change within a land use area from that use to another;

2) change in or at land use boundaries;

3) change in category involving no boundary changes (may result from original misclassification); and

4) change in land use due to omission not mapped originally.

Caution should be exercised, however, when identifying areas of land use change to insure that possible differences in appearance or signature of the same feature at two different times are not identified as changes. This possibility may result from differences in the time of year, sun angle, quality of photography, and scale of the photography.

Land use change boundaries are first marked on the 1970 photography overlay. Changes are noted by marking the former land use digits first, followed by a dash and the digits of the new land use. Thus a polygon or area marked by a (21-11) has changed from cropland or pasture to urban residential. Once all changes have been identified and marked on the photo overlay, they are carefully transferred to an overlay registered to the photomosaic and 1970 land use overlays.

INTERPRETATION AND COMPILATION FROM LANDSAT IMAGERY

LANDSAT imagery is available in several formats, and like high-altitude photography, its quality varies greatly depending upon atmospheric conditions, time of year, and processing. CARETS interpreters have found that the best form of imagery for land use mapping is the color composite transparency. This was used in the land use mapping of CARETS at a scale of 1:250,000. Color composite transparencies or prints, however, are very expensive relative to black and white imagery, and for that reason this report will also provide aids for land use mapping using the less expensive formats.

In preparing overlays for the mapping of CARETS from LANDSAT data, the decision was made to use the format of the USGS 1:250,00-scale topographic sheets slightly modified by attaching the CARETS portions of the Charlottesville and Roanoke sheets to the Washington and Richmond sheets (figure 2-2). The margins of the overlay sheets were then traced directly from the topographic maps onto appropriate sized sheets of frosted acetate drafting film.

Before registering the overlay to a LANDSAT transparency, the transparency, in half frame format, was placed in a clear acetate protective sleeve and kept from slipping with register pins. To register an overlay to a LANDSAT transparency, the transparency was first placed over the topographic sheet on a light table, brought as closely as possible into register with it, and then taped to the map. The overlay's margins were registered with those of the map and the overlay taped onto the LANDSAT transparency. With the overlay secure on the transparency, the topographic map was removed and the overlay was ready for compilation and mapping.

Since at least two or more LANDSAT half frame transparencies are needed to map the area of the topographic sheet, the registration process must be repeated for every change in transparency. In CARETS the registration was facilitated by numerous sharp boundaries between land and water. In areas where such boundaries do not exist, registration may be much more difficult.

Interpretation

The manual interpretation of land use from LANDSAT consists primarily of identifying and marking the boundaries between differing land uses on an overlay. This often entails the separation of different spectral signatures, identification of specific features by shape or size, or the determination of the land use characterized by a specific

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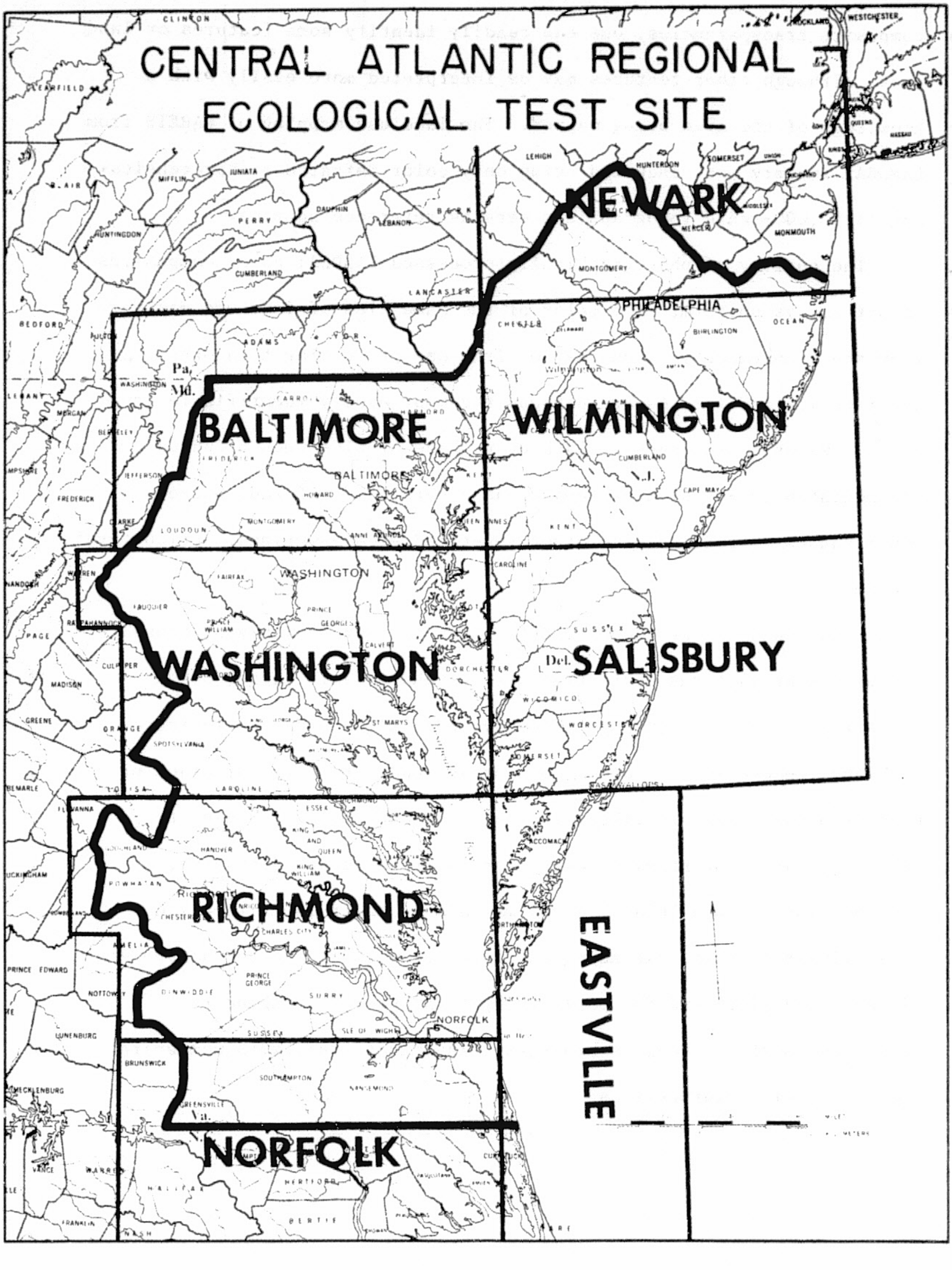


texture or pattern. In interpreting LANDSAT images in the form of color composite transparencies, one can readily identify some features or land uses, although other features may be interpreted more easily with a knowledge of the area being mapped. The land use mapping of CARETS from LANDSAT imagery was conducted using only color infrared transparencies and 1:250,000-scale topographic sheets as reference sources.

The quality of photographically processed LANDSAT color composites is not always uniform. The color of the same kind of land use may vary from one transparency to another or from one processing to another. Water bodies and forests are perhaps the most easily identifiable land types. Water bodies appear black or a shade of blue when affected by sedimentation. Forest areas appear as a dark shade of red, whereas other shades of red indicate other vegetated areas--wetland, agricultural, or urban.

Urban land may be identified by light to dark bluish-gray tones and by linear patterns indicating streets and roads. Large, often geometrical areas of red surrounded by urban signatures may indicate parkland, cemeteries, or other open urban land. Features of black or dark blue in urban areas are likely to represent extremely high density buildings, areas of heavy industry, or railroad yards. The size, shape, and location of such "black" areas may aid in their identification. Short linear features extending out into the water indicate the presence of docks and piers and the possibility of warehouses being nearby. Commercial strips appear as blue-gray linear patterns, with commercial nodes at their intersections.

Residential urban areas, because of their great diversity, are represented by numerous different spectral signatures. High density residential areas in the central city appear dark blue and are indistinguishable from surrounding commercial and industrial areas. Less dense residential areas appear as blue mixed with red and white. Large treeless tracts of single family residences have distinctive signatures, which under some processing, appear to be a light, grainy beige, similar in color to agricultural land, but differing by being too large and unbroken by forests to represent field patterns in CARETS. The boundaries between these residential areas and forest is normally sharper than that between agricultural and forest land. Older and wooded residential areas are often very difficult to distinguish from forest land. It is also extremely difficult to distinguish between suburban and adjacent agricultural lands.

Agricultural land in CARETS may appear as any combination of colors from white to gray to pink to brown to red. Most CARETS rural land that is not in forest is in agriculture. Such land is often best identified by field shapes and patterns.

CARETS nonforested wetlands, most commonly occurring in coastal lands and on flood plains, appear on a LANDSAT color composite as muted purple or brown (depending on the processing). Often such wetlands are penetrated by numerous winding streams. Salt marshes present the problem of being inundated during high tides, but are more easily detectable during low tides.

Barren land is often hard to differentiate from agricultural land, extractive lands, or land under construction, but is easiest to recognize as a distinct white signature. Sand beaches are easily detectable as narrow white strips along the edge of coastal land. Many of these categories identified on LANDSAT imagery, such as railroad yards, airports, highways, and single-family residential areas, are in fact Level III categories, but cannot be interpreted with any degree of regularity.

Black and white enlargements are easier to produce and much less expensive, but they are more difficult to work with and present problems that color images do not.

Interpreting LANDSAT imagery, using black and white prints at 1:250,000 scale, may be facilitated by comparing prints from two different bands, preferably bands 5 and 7. Band 5 is sensitive to the longer wavelengths (red) of the visible spectrum, between 600 and 700 nm. Black and white prints of band 5 provide the greatest contrast between forest and cleared land and the greatest resolution in urban land use. Band 7, sensitive to wavelengths between 800-1100 nm in the near infrared, is beneficial for enhancing water areas, and penetrating atmospheric haze and pollution. Wetlands are difficult to resolve using an individual print of either band, but may be distinguished with relative certainty by comparing both bands.

Imagery of an area from two different seasons also facilitates interpretation. Features that blend together in one season may easily stand out in the next. Recently harvested and plowed agricultural fields contrast strongly with forest areas in the fall but reflect radiation of similar wavelengths to forests in the summer. Snow aids in detecting cleared land in the winter. Wetland areas, which are difficult to interpret on LANDSAT imagery but vary depending on season, moisture, and temperatures, can be most easily mapped by comparing prints from three or four different seasons.

Seasonal tone differences are subject to discrepancies caused by variations in photo processing and daily atmospheric differences. Therefore, it is necessary to compare several LANDSAT images for any interpretation, and no one signature can be ascribed to a single land use.

A breakdown of Level I classifications and resulting signatures for black and white enlargements is shown in table 2-6.

For optimum interpretations in a single season, fall imagery provides the greatest resolution for spectral bands 5 and 7. The atmospheric conditions at the time of the LANDSAT pass and the quality of the reproduction, however, have the most significant effect on the capabilities of any one print.

Analysis of LANDSAT/Level I Land Use Mapping Accuracy

The determination of accuracy for the Level I LANDSAT-derived land use map was based on a check of 30 randomly sampled points throughout the Norfolk test site using the existing UTM grid as it appears on the Norfolk and Virginia Beach photomosaic sheets. Pairs of one to three-digit nonrepeating random numbers were extracted from a table (Rosander, 1951) and applied to this grid as though they were UTM grid values.

Table 2-6--Image signatures by land use category for LANDSAT visible and near infrared black-and-white imagery

Land Use	BAND 5		BAND 7	
	Signatures	season	Signatures	season
URBAN	med to dark gray center city only Road patterns	fall (Oct.)	light gray linearity or solidity to pattern	fall (Oct.)
AGRICULTURE	very light gray, drainage field patterns	fall	very light gray white, field drainage patterns	winter
FOREST	dark gray or med gray	winter	dark gray	winter
WATER	med gray variates to light gray near shore	all	dark gray to black solid	all
WETLAND	lack of drainages gray-w/standing water	winter	dark gray black	all
BARE LAND	white	all	light gray	all

Point 4045000 mN., 366000mE., UTM Zone 18, represents the origin of the sampling area.

Each sample point was plotted on a 1:250,000-scale reduction of the Norfolk and Virginia Beach photomosaics and then transferred to its corresponding position on the 1:100,000-scale, Level II land use maps, and the 1:250,000 scale, LANDSAT-derived land use maps. Having been extensively checked and revised for accuracy, the Level II map was assumed to be ground truth. In this example, then, LANDSAT accuracy, at Level I, is a function of the number of LANDSAT land use polygon interpretations that are the same as aircraft land use polygon interpretations. Researchers found that of the 30 randomly sampled points, 26 were correctly identified using LANDSAT, and thus the LANDSAT land use interpretation was determined to be approximately 87 percent accurate. Table 2-7 compares LANDSAT and aircraft interpretation results for the 30 sample points.

A separate accuracy figure for the Level I land use map derived from LANDSAT imagery was also determined using an aligned stratified sampling procedure. The method employed was that of comparing LANDSAT and aircraft land use data at the points of intersection of a 1-km grid overlayed on each land use map. The Level II high-altitude aircraft map at 1:100,000 was compared with the Level I LANDSAT map at 1:250,000, and 1-km grids, corresponding to the UTM coordinate grid with the origin at 404,500 m north and 367,000 m east, Zone 18, were superimposed on both maps. Every intersection was sampled to insure a uniformly distributed sample of 1989 points across the Norfolk test site.

Table 2-7--Comparison of Level I LANDSAT and aircraft interpretation for 30 sample points

SAMPLE SITE	LANDSAT 1972 LAND USE - 1:250,000	AIRCRAFT 1972 LAND USE - 1:100,000
1	1	1
2	1	1
3	1	1
4	6	5
5	1	1
6	1	1
7	1	1
8	1	4
9	4	4
10	1	2
11	4	4
12	4	4
13	2	2
14	4	4
15	2	2
16	2	2
17	2	2
18	4	4
19	4	4
20	2	1
21	4	4
22	4	4
23	4	4
24	4	4
25	4	4
26	2	2
27	2	2
28	2	2
29	5	5
30	2	2

Key to Level I categories:

1 - Urban and built-up
2 - Agriculture
4 - Forest
5 - Water
6 - Nonforested wetland

By this sampling procedure, 1521 or 76.5 percent of the points sampled were mapped with the same Level I classification on the maps derived from LANDSAT imagery as those derived from the high-altitude aircraft photography. Of the classification differences that occurred, the most significant were of three types: (1) areas interpreted as agricultural land from the high-altitude aircraft photography but as urban land from the LANDSAT imagery; (2) areas interpreted as forest from the photography but as agricultural land from the imagery; and (3) areas interpreted as agricultural land from the photography but as forest from the imagery. A complete comparison is presented in table 2-8.

CARETS researchers mapped these differences to show the orientation of discrepancies in respect to the test site and to each other. The major concentration of interpretation differences forms a wide belt along the urban/rural fringe. Researchers examined these points on the data base to identify the criteria for the interpretation decision at each scale and to determine the types of errors resulting in interpretation differences.

For each site researchers recorded one of four possible reasons for discrepancy and produced maps showing the distirbution of each source of error. They found four possible sources of error or explanations for the discrepancies between the maps from aerial photography and LANDSAT imagery: (1) sampling points falling on a boundary between two land uses were arbitarily assigned one of two uses, and discrepancies resulted when assigned uses differed between the two maps; (2) land use parcels mapped from the aerial photography were below the minimum mapping size for the LANDSAT-derived map; (3) multiple land covers occurred on

Table 2-8--Comparison of Level I LANDSAT and Level I aircraft interpretations at 1-km grid intersections

Aircraft Level I	LANDSAT LEVEL I 1	2	4	5	6	7	Total a/c
1	324	27	31	19	0	2	403
2	78	347	74	1	0	0	500
4	48	87	613	4	2	0	754
5	18	4	10	186	12	1	231
6	4	5	22	17	35	2	85
7	1	0	0	2	0	13	16
Total LANDSAT	473	470	750	229	49	18	1,989

the same land parcel, but the predominant aircraft photography signature (and thus the classification) differed from the predominant signature for the same parcel on the LANDSAT imagery; and (4) interpreters misclassified land use from the LANDSAT imagery.

Examples of these problem areas can be seen in figures 2-3, 2-4, and 2-5. From this information, the location of the greatest inconsistencies in the LANDSAT and aircraft land use maps and the reasons for these occurrences were identified. Table 2-8 presents a comparison of the number of classification differences with the cause for the discrepancies.

The greatest number of interpretation differences resulted from the method of selecting points on the aircraft land use maps for comparison with the LANDSAT. The boundaries between land use on the aircraft maps frequently did not correspond exactly to the boundaries on the LANDSAT maps. By comparing points on the aircraft maps with points on the LANDSAT maps, one could detect differences that did not actually result from interpretation problems, but rather from those of registration. Forty percent of the points of discrepancies in interpretation between LANDSAT and aircraft source materials were due to thi problem of sampling. These samples were distributed fairly evenly across the region, excluding the areas of the Dismal Swamp and Back Bay where no real interpretation differences occurred. See figure 2-6.

The second cause for discrepancies between LANDSAT and aircraft interpretations resulted from the generalization due to the minimum mapping unit at the different scales. Areas as small as 4 ha (10 acres) can be interpreted at 1:100,000 scale, whereas with LANDSAT imagery at 1:250,000 scale, the smallest area one can map is 25 ha (60 acres). This difference in minimum mapping area accounted for 20 percent of the

Areas of Interpretation Differences on ERTS Image

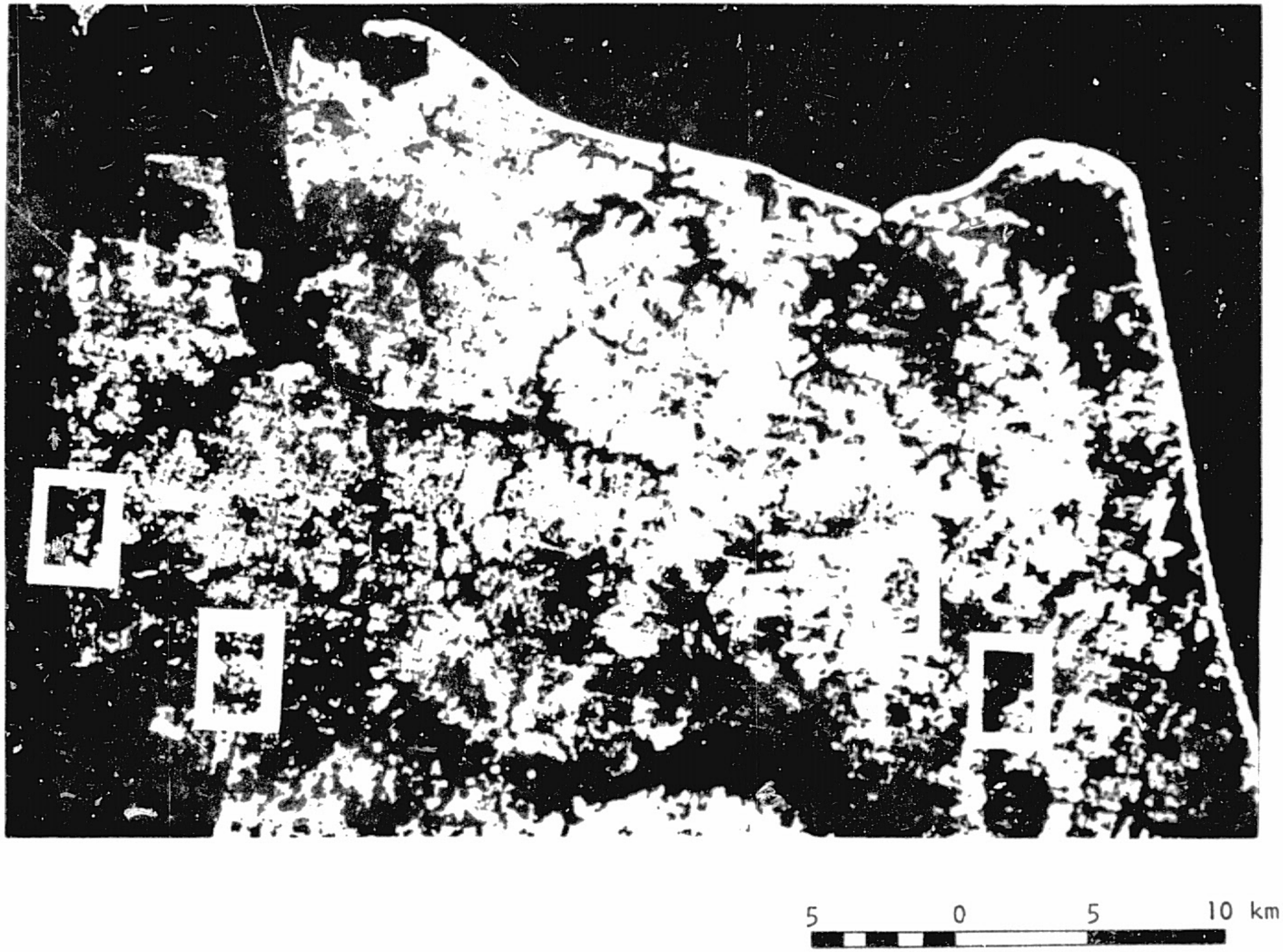


Figure 2-3--LANDSAT image 1:250,000. Areas outlined are examples of areas where interpretation discrepancies occurred.

Areas of Interpretation Differences on ERTS Level 1 Map

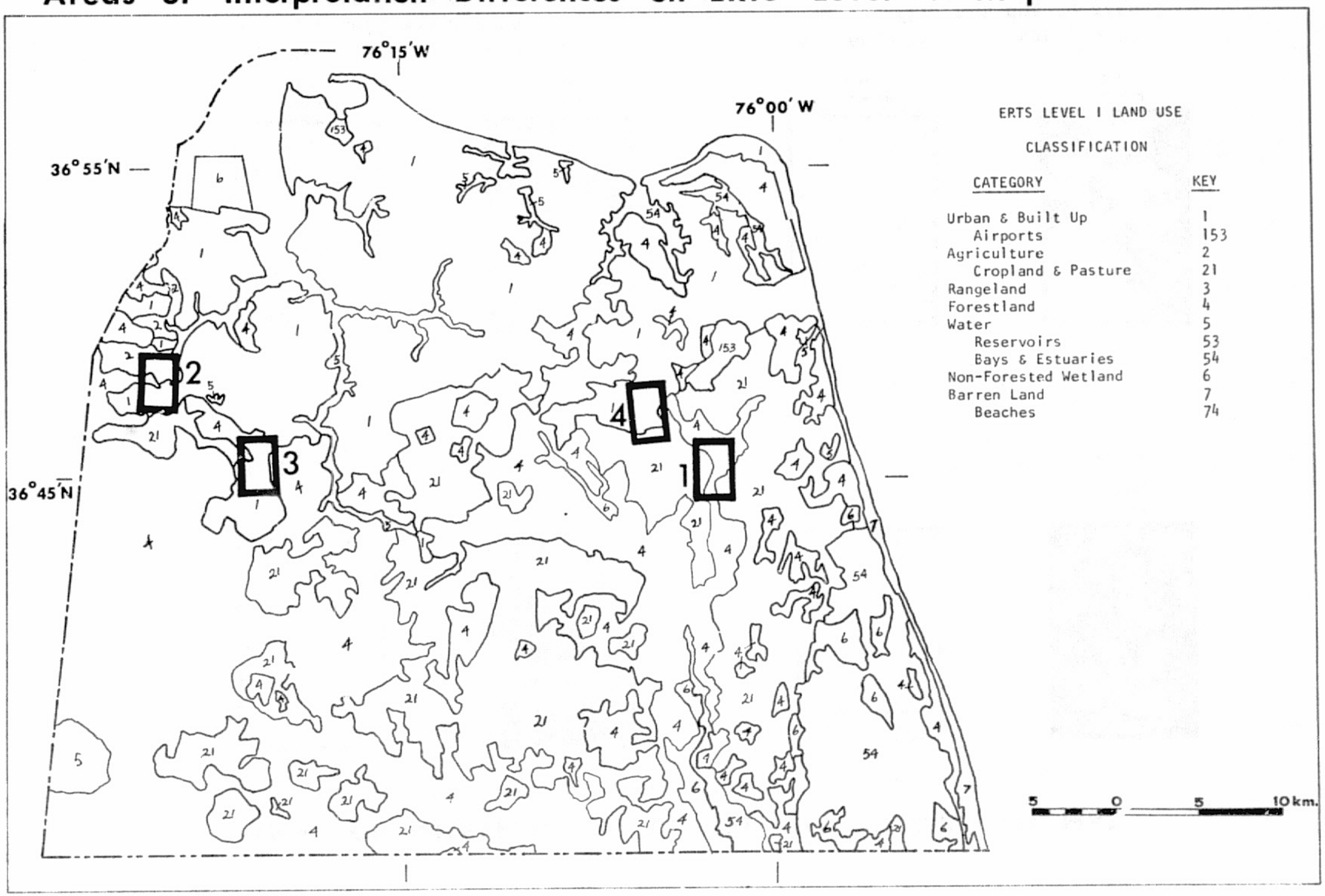
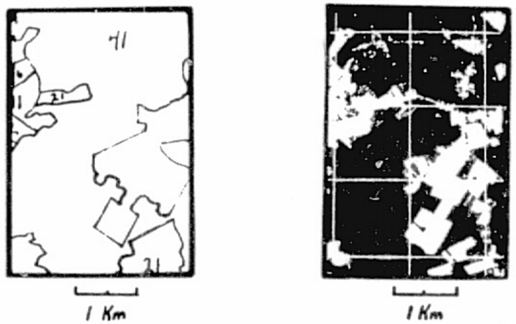


Figure 2-4

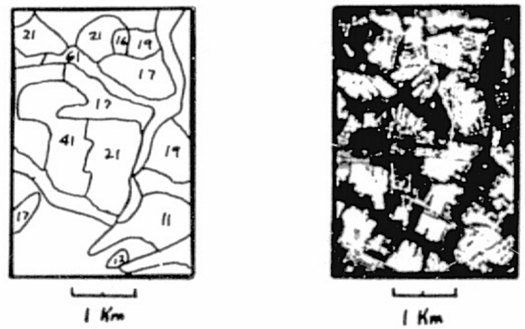
ERTS Level I Land Use Map. Areas outlined are examples of areas where interpretation discrepancies occurred.

AREAS OF INTERPRETATION DIFFERENCES ON AIRCRAFT MAP

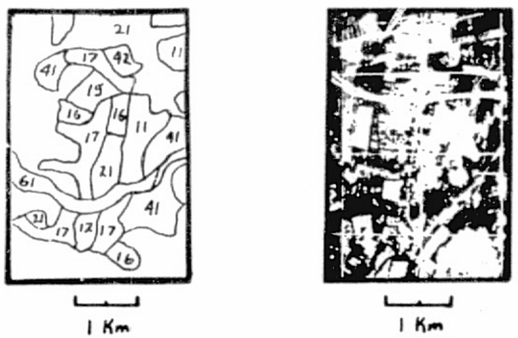
AIRCRAFT MAP (LEFT) PAIRED WITH AIRCRAFT PHOTOGRAPHY (RIGHT)



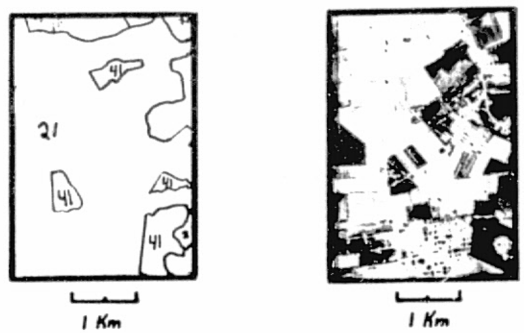
1. Area in discrepancy with the ERTS map due to the point selection technique. See Figure 2-4, number 1.



2. Area in discrepancy with the ERTS map due to the larger minimum mapping size on ERTS. See Figure 2-4, number 2.



3. Area in discrepancy with the ERTS map due to a multiplicity of land uses with differing signatures on ERTS and aircraft sources. See Figure 2-4, number 3.



4. Area in discrepancy with the ERTS map due to actual misclassification of the ERTS. See Figure 2-4, number 4.

Figure 2-5

LOCATION OF INTERPRETATION DIFFERENCES DUE TO THE POINT SAMPLING TECHNIQUE

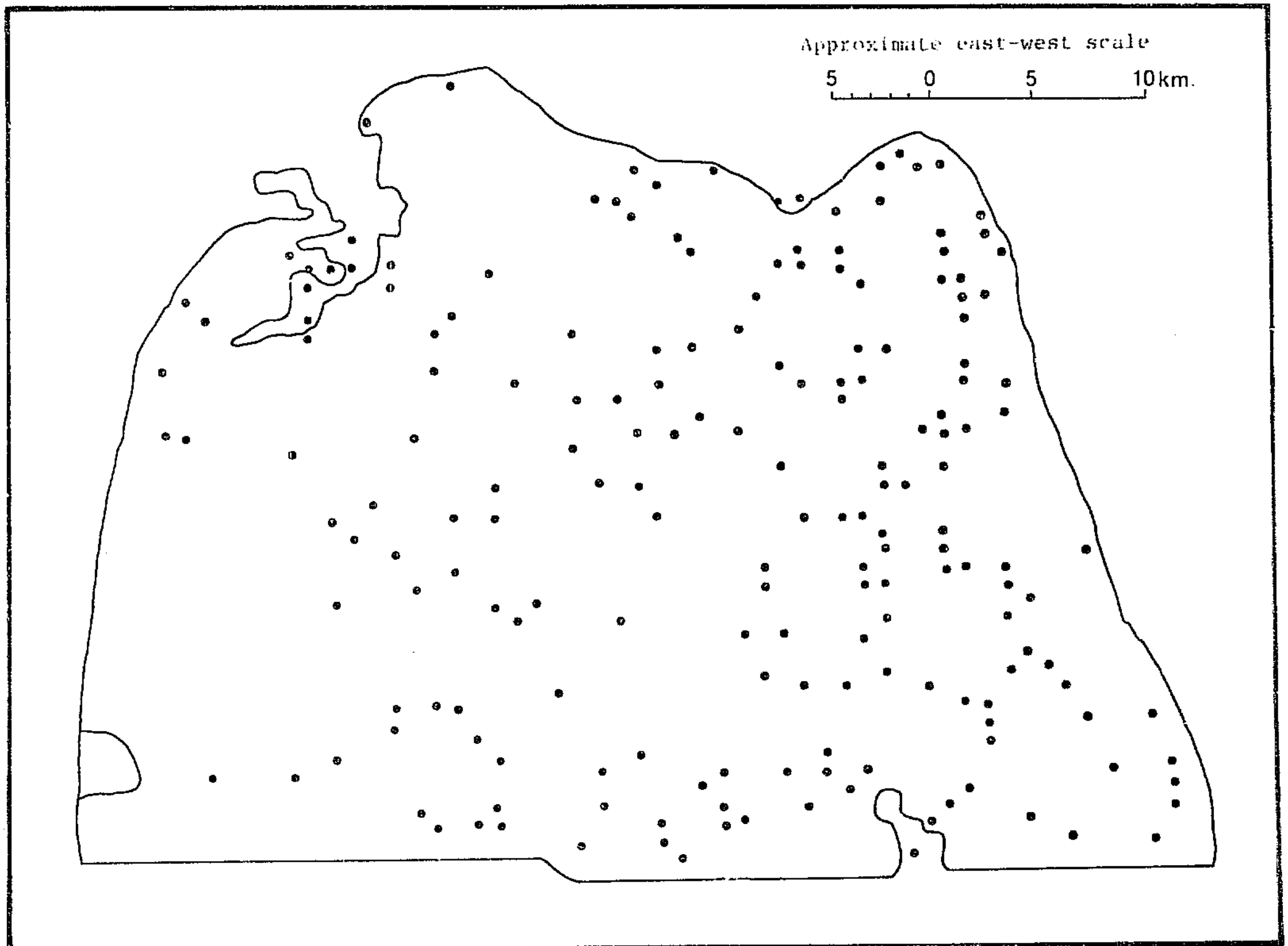


Figure 2-6--Unrect[illegible] computer-generated map showing points of interpretation differences on LANDSAT and aircraft land use maps due to the point sampling technique.

interpretation differences. These differences were also distributed across the total area with the exception of the Dismal Swamp and Back Bay, which are areas of only one land use type. See figure 2-7.

The third factor affecting interpretation differences, accounting for a significant number of the differences in the urban-suburban fringe areas, consisted of interpretation differences caused by the presence of more than one category of land use in a mapping unit with differing spectral characteristics on aircraft photography and LANDSAT imagery. An example of such would be a tree-covered residential area, classified as forest from the LANDSAT imagery and residential from the aircraft photography. The interpretations of the data disagreed, yet neither could be considered incorrect, since each i[illegible]pretation reflected adequately the information portrayed on eac[illegible]ective scene. Twenty percent of the interpretation differences were attributable to the problem of differing dominant signatures. See figure 2-8.

The final cause for interpretation differences was actual misinterpretation of the LANDSAT imagery. The majority of these errors occurred in the regions of gradation from suburban to agricultural land use. LANDSAT imagery cannot resolve isolated land use patterns and must rely on surrounding color tones. Where gradations occur between these tones, texture becomes important. Between the suburban and small farm areas, there are very few tone and texture differences, and the LANDSAT imagery, which is more sensitive to vegetative signatures, cannot distinguish between a dispersed settlement pattern and dissected agricultural fields. Nineteen percent of the interpretation differences were actual interpretation errors. See figure 2-9.

LOCATION OF INTERPRETATION DIFFERENCES DUE TO DIFFERENCES OF MINIMUM MAPPING SIZE

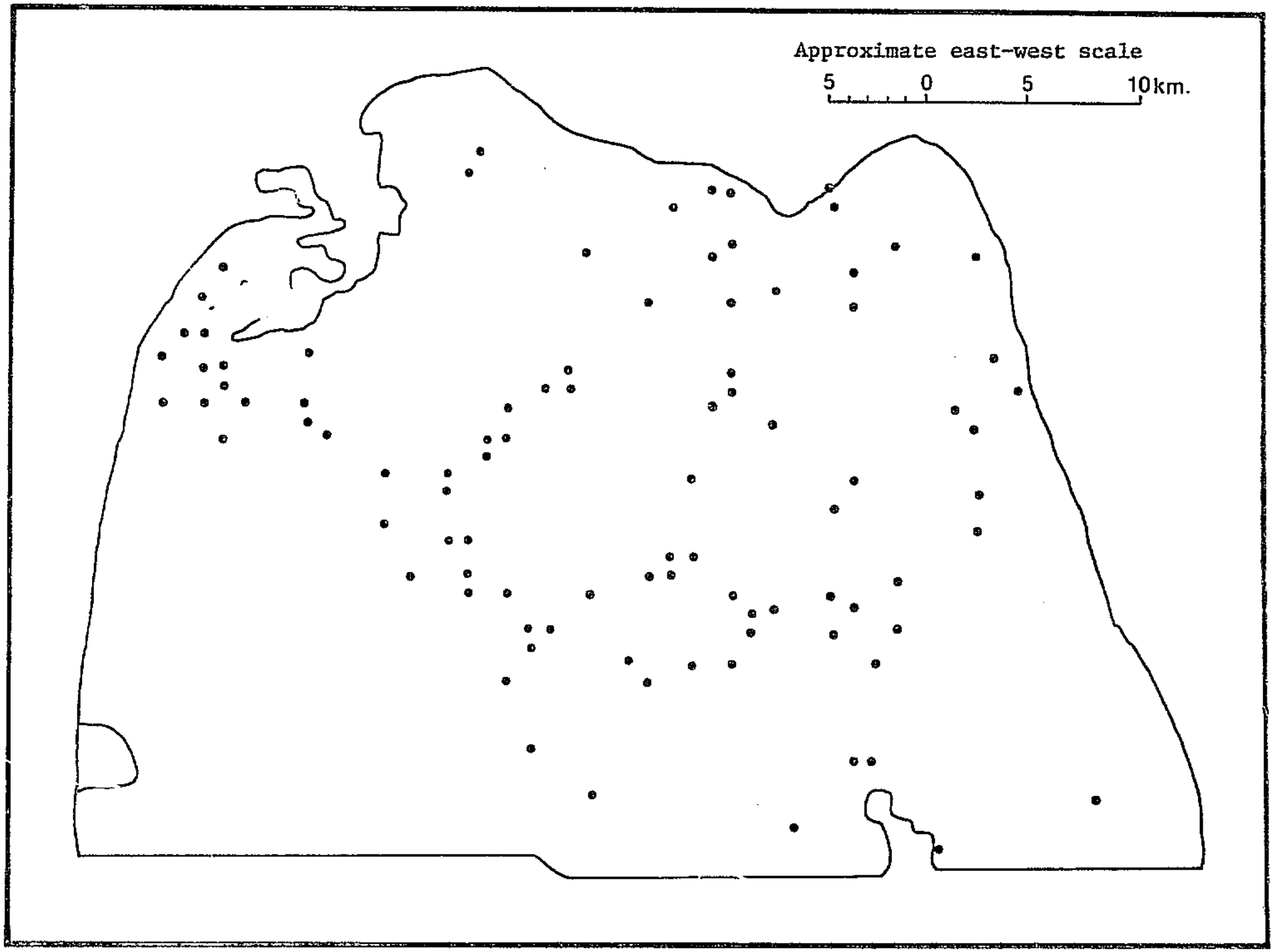


Figure 2-7--Unrectified computer-generated map showing points of interpretation differences on LANDSAT and aircraft land use maps due to the larger minimum mapping size of LANDSAT imagery at 1:250,000.

LOCATION OF INTERPRETATION DIFFERENCES DUE TO INTERMIXTURE OF LAND USES

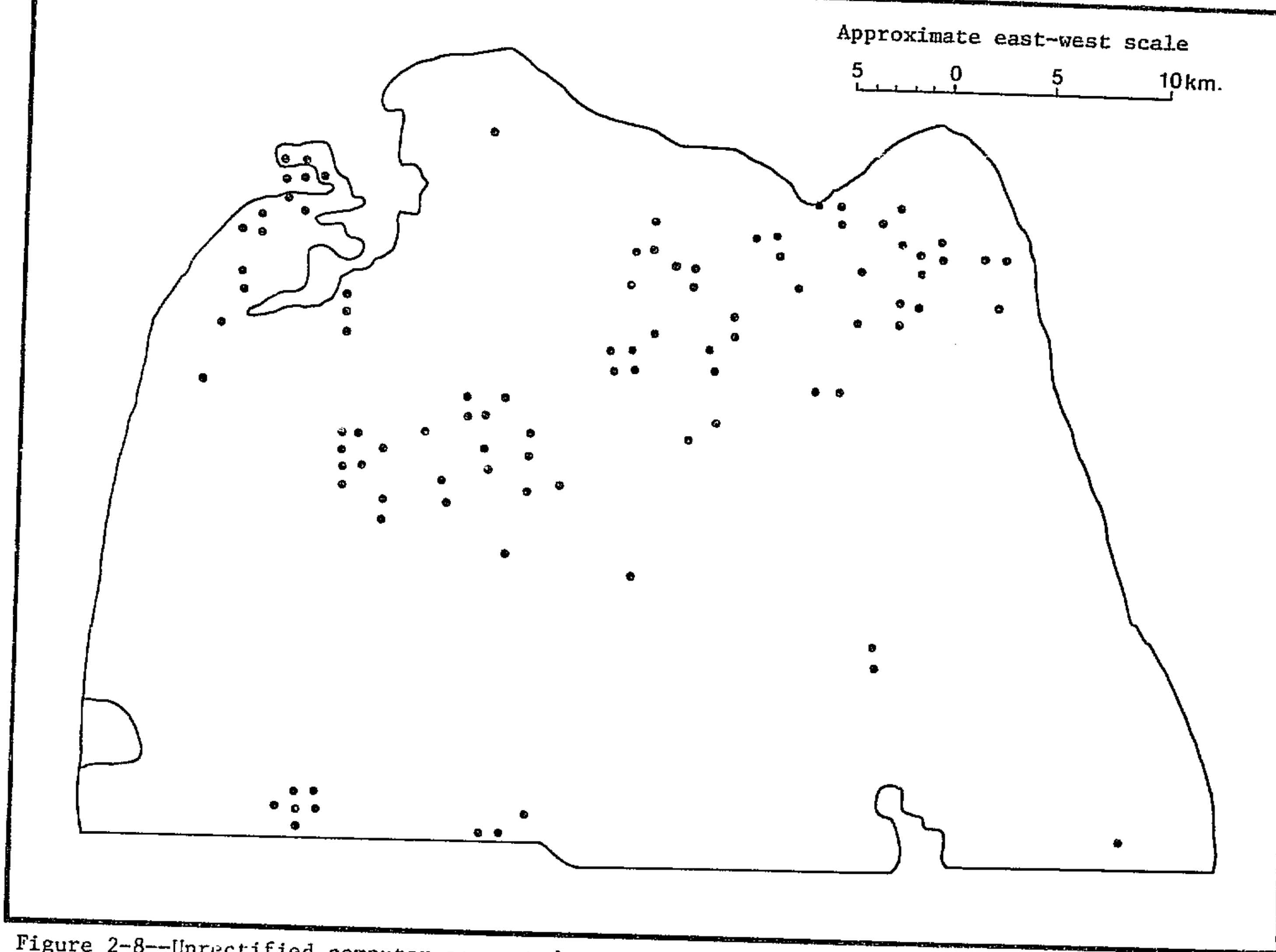


Figure 2-8--Unrectified computer-generated map showing points of interpretation difference on LANDSAT and aircraft land use maps due to a heterogeneous mixture of land uses at a site with differing dominant signatures on the LANDSAT and aircraft sources.

LOCATION OF INTERPRETATION DIFFERENCES DUE TO MISCLASSIFICATION OF THE LANDSAT IMAGE

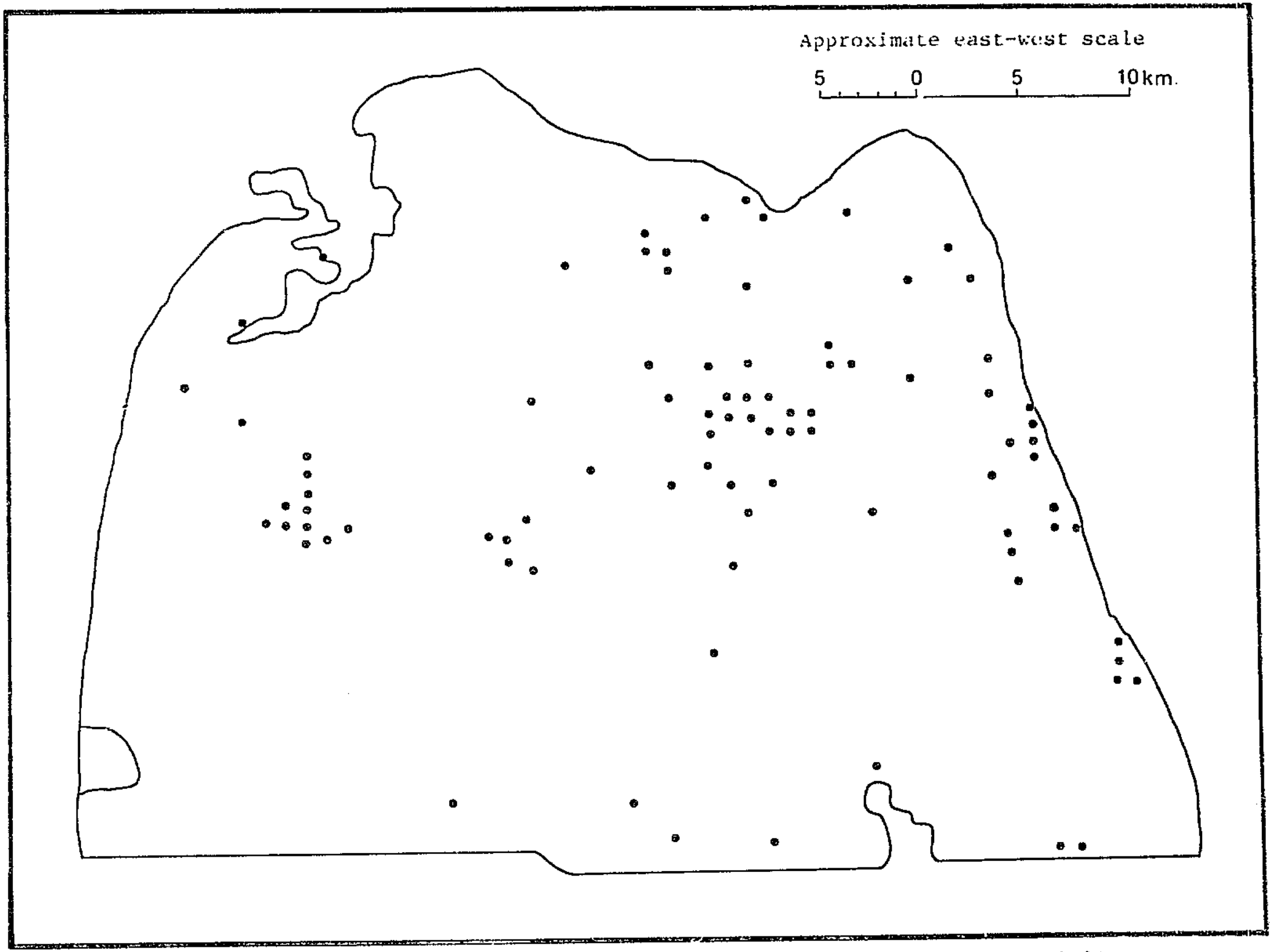


Figure 2-9--Unrectified computer-generated map showing points of interpretation differences on the LANDSAT and aircraft land use maps due to actual misclassification of the LANDSAT data.

Two significant spatial patterns were apparent in the analysis of interpretation differences. In the suburban fringe area, the LANDSAT interpretation was generalized to the most intensive land use, whereas the high-altitude photography provided greater detail, allowing each parcel of land use to be extracted. At the periphery of this region the LANDSAT system was inadequate for resolving boundaries between urban and built-up and agricultural land. LANDSAT was found to have the greatest error along this border.

With the exception of urban-rural fringe areas where multiple land uses are intermixed, most Level I land uses can be accurately interpreted using LANDSAT imagery. The areas that cause trouble for LANDSAT are those in which different land uses are so small and heavily intermixed that boundaries between them cannot be drawn. Although the Level I classification is fairly broad and generalized, it does not account for possible mixtures of different Level I categories. These unclassifiable areas seem to be most prevalent on the urban-rural fringe and help explain many errors and discrepancies.

Comparison of CARETS and Published Data Sources

Although a comparison of land use area summaries derived from CARETS data with those obtained from published sources does not definitively address the issue of CARETS data accuracy, it may reveal a similarity between remote sensor data and that derived from other sources or a lack of accuracy in one of the data sources. Unfortunately, data sets comparable in category definition, area covered, and year compiled to CARETS data are difficult to find, and only a limited number of categories could be compared in this study.

A comparison of CARETS and published measurements of the total area of urban land use in the Norfolk test site was not possible for a lack of compatible land use classifications. Published figures for certain Level II land uses comparable to the CARETS categories were available. Table 2-9 presents the areas in hectares of residential, commercial, and industrial land in the Norfolk test site as measured from CARETS 1970 land use maps (at a scale of 1:50,000 by the Canada Geographic Information System) and from a 1965 land use map compiled at a scale of 1:19,200 by the Southeast Virginia Planning District Commission (SEVPDC). One can assume that the SEVPDC's data are more accurate for 1965 than the CARETS data for 1970 because the former were compiled by planners more familiar with the area and because the measurements were derived from a much larger scale map.

Given the rapidly expanding nature of urban residential areas in the test site and the 5-year time differential, the two data sources for residential land use compare fairly well. Such is not the case, however, for commercial and industrial land use. For the commercial category, the CARETS figures greatly exceeded those published, but for the industrial category published figures greatly exceeded those for CARETS. The explanation for this may rest either in interpreter error or in differing definitions of the land use categories. The sums of industrial and commercial land use areas from CARETS and published sources, are similar enough to suggest that extensive industrial areas were classified as commercial on the CARETS maps. Small, difficult-to-identify industries in commercial areas or misclassified industrial park areas might help

Table 2-9--Residential, commercial, and industrial land use, Norfolk test site

	Area in Hectares Measured from CARETS 1970 Land Use Maps	Area in Hectares Measured from SEVPDC 1965 Land Use Map
Residential land use	22,066	17,459
Commerical land use	3,943	1,734
Industrial land use	1,536	3,575
Commercial and Industrial land use	5,479	5,310

explain part of this discrepancy as might warehousing and storage facilities associated with an industry, which CARETS interpreters considered commercial, but the SEVPDC may have classified as part of a closely associated manufacturing plant.

The U.S. Census of Agriculture for 1969 provides the most up-to-date published data set for comparison with CARETS agricultural data. The total area in farms for Virginia Beach and Chesapeake in 1969 was reported to be 49,336 ha of which 7,877 ha were cropland, and the remaining farmland (41,459 ha) consisted of woodland, woodland pasture, and all other land (i.e. roads, homesteads). The total area of farmland as shown in table 2-10 compares favorably with cropland and pasture area totals derived from aircraft (48,475 ha) and LANDSAT (48,047 ha) data. The comparison between LANDSAT and aircraft data and the Census of Agriculture's total farmland excluding woodland and woodland pasture for 1969, however, is not quite as favorable.

There are several possible explanations for the differences between the CARETS and published data sets. The time factor is important to consider. Agricultural census data were compiled in 1969, whereas aircraft and LANDSAT data were compiled from 1970 photography and 1972 imagery, respectively. Also, the Census of Agriculture figures were derived by using a sampling questionnaire, whereas CARETS data were obtained by area measurement from a land use map. Finally, CARETS cropland and pasture data include all parcels of nonagricultural land smaller than a square, 200 m on a side, representing the minimum mapping

C. 2

Table 2-10--Agricultural and forest land use, Chesapeake and Virginia Beach

	CARETS 1970 Aircraft Data in Hectares	CARETS 1972 LANDSAT Data in Hectares	Published Data
Agricultural land use	48,475	48,047	49,336* 41,459**
Forest land use	75,479	74,669	76,829***

*Total cropland and other farmland including woodland, and woodland pasture derived from the 1969 U.S. Census of Agriculture

**Total cropland minus woodland and woodland pasture

***Includes all areas having at least 50 woody stems per acre, derived from 1965 Forest Service Survey unit of 2 mm--roads, homesteads, and small woodlots, in contrast to the Census of Agriculture's more detailed breakdown of agricultural land use.

Comparison of CARETS and published forest area data for Chesapeake and Virginia Beach presents similar problems. The most recent forest survey of the test site was completed in 1965 by the U.S. Forest Service, when the total forest land area was found to comprise 73,574 ha. These forest land (defined as areas having at least 50 woody stems per acre) statistics were compiled from U.S. Department of Agriculture's 1964 1:20,000 aerial photography. They compare favorably with CARETS aircraft (75,479 ha) and LANDSAT (74,669 ha) statistics.

Change Detection Procedures Using LANDSAT Imagery

October and December 1972 LANDSAT imagery was used to test the sensor's applicability for detecting land use change and to provide a prototype for a change detection study for all of CARETS. The basic procedure involved overlaying a 1970 land use map on a 1:100,000-scale color infrared 1972 LANDSAT transparency covering the Norfolk area and then mapping areas appearing to have changed on drafting film overlying a photomosaic of the same area. The interpreter used 1970 and 1972 high-altitude photography of the area to verify the detected change.

First, the LANDSAT image and the 1970 Level II land use overlay were compared to discover unexpected hues and tones, i.e. areas that might have changed. If a possible change were noted, the interpreter determined the nature of the change and the classification Level (I, II, III) to which it could be discriminated. The interpreter then compared the 1970 and 1972 photography to verify the change and the correctness of the interpretation. Actual changes were mapped on the second overlay with black pencil and identified in accordance with established CARETS mapping procedures. "False" changes, suggested by the imagery but not actually occurring, were mapped on the same overlay in orange pencil. All of the land use polygons were given identification numbers and "from-to" change maps were prepared for 1970-72 at Levels I and II. Level I and II change areas that could not be identified on LANDSAT images without recourse to supplementary high-altitude aerial photography were also noted. The change areas were then measured by dot planimeter and summarized in appropriate categories.

Some of the observations regarding LANDSAT as a tool for change detection are listed below:

1) Areas undergoing heavy construction are identifiable to Level III. The use of spring-time imagery (April-May) will reveal if these areas are plowed fields, which did not appear to be the case on either the September or December imagery used.

2) On the October and December imagery, many of the agricultural fields (probably stubble) reflected a blue-gray spectral response similar to inhabited urban areas, accounting overwhelmingly for the false changes that were mapped. These problems may be "seasonal" and capable of being resolved with early summer imagery.

3) Older residential areas with heavy tree cover appear on LANDSAT images as forest.

4) At Level II, institutional, commercial and industrial categories cannot be separated on LANDSAT images.

5) Many urban changes are difficult to observe unless the land is disturbed at the time of the imaging. For example, some urban renewal projects were started and completed in the 2-year time span, and although the change was slightly noticeable on LANDSAT, it would not have been mapped without the attendant aircraft photography.

6) A masking device 5 cm^2 is useful in interpreting changes.

7) All category 19 (urban open and other) areas should be checked for completion of construction changes at the later date as a matter of course, since it is more difficult to detect the completion of the construction than its start.

Table 2-11 presents the areas of land use change derived from this LANDSAT change detection experiment. Total Level I and Level II land use changes in the Norfolk test site included 3,916 ha (9,676 acres) or 39.2 km^2. This figure compares favorably with the amount of change detected for the years 1959-70 from photography, but it greatly exceeds the amount of change detected using aircraft data alone in the subsequent CARETS change detection study. This difference is probably best explained by the thoroughness of the LANDSAT change detection study, measurement errors in one study or the other, or the differences in the expertise of interpreters. Interpreters did not map Level II change for 1959 to 1970.

Table 2-11--Results of 1970-72 land use change analysis using LANDSAT and high-altitude aircraft photography

	Hectares	Acres	Percent
a. Area analyzed (Norfolk test site)	198,564	490,644	
b. Total aircraft-verified land use change, Level I	2,924	7,225	
c. Aircraft-verified change correctly identified on LANDSAT, Level I (h&i)	2,652	6,553	
d. Percent of Level I change correctly identified with LANDSAT			90.7
e. Total aircraft-verified land use chang.., Level II (including that which changed at Level I)	3,216	7,947	
f. Aircraft-verified change correctly identified on LANDSAT, Level II (hi&k)	2,944	5,595	
g. Percent of Level II change correctly identified with LANDSAT			69.8
h. Aircraft-verified change correctly identified on LANDSAT, to Level II, between Level I categories	1,952	4,823	
i. Changes identified on both aircraft and LANDSAT at Level I only	700	1,730	
j. Total aircraft-verified land use change occurring at both Levels I and II (e&i)	3,916	9,676	
k. Aircraft-verified change correctly identified on LANDSAT, to Level II within Level I categories	292	722	
l. Percent of test site total area involved in aircraft-verified change [(j÷a) x 100]			2.0
m. "False change (erroneously indicated by LANDSAT interpretation)	6,432	15,893	

Of the 2,924 ha (7,225 acres) of Level I land use changes, 2,652 ha (6,553 acres) or 90.7 percent were visible and identifiable on the LANDSAT imagery.

Further analysis of the statistical summaries reveals that interpreters correctly identified 1,952 ha (4,823 acres) of Level II change occurring from one Level I category to another, and 292 ha (722 acres) of Level II change within Level I categories. Moreover, investigators detected 616 ha (1,521 acres) of land use change from LANDSAT imagery, the precise nature of which could not be identified without reference to supplementary high-altitude aircraft photography. An additional 356 ha (880 acres) of change actually occurred but did not appear on the LANDSAT imagery in any identifiable form.

Using LANDSAT data CARETS interpreters could identify successfully some classes of changes but not others. Interpreters identified change from forest to agricultural land and from forest and agriculture to urban land uses at Level I. They also successfully identified the following Level II changes: from cropland and pasture and heavy crown cover forest to urban residential and urban open and other (19). Many changes from urban open to residential, however, required high-altitude aircraft photography for positive identification. Interpreters could not detect some change on the LANDSAT imagery, including change from heavy to light crown cover forest, and change from nonforested wetlands to reservoirs. The size of these areas appears not to be a factor in the difficulty of their detection.

Interpretation of change in this fashion required 88 man-hours, of which approximately 32 were devoted to the interpretation and initial mapping process and the remainder to the preparation of graphics (Alexander, 1973).

Computerized Data Handling and Analysis

Computer manipulation of the CARETS graphic data base has been the focus of the project's data handling plan. Procedures for data handling and analysis revolve around the use of the Datagrid digitizer. The digitizer is a high precision coordinate measuring unit that converts geographical data (e.g. CARETS land use maps) into digital form for computer applications. The general concept is shown in figure 2-10. Map data are digitized into a computer format, stored in an appropriate form, processed in a central computer and output requested in either tabular or plotted line form. There are four primary hardware components in this information system: the input device (digitizer), storage device (tape, disc, or cards), a processing capability (programmed computer with data enquiry link), and output device (plotter).

The CARETS project as part of its broad research orientation has attempted to explore available technology in the graphic-based information system field. At present, the system is still being developed, though several selected data sets have been analyzed by the Canada Geographic Information System (CGIS) and are presented in this report. The procedures used by the CGIS are summarized as follows:

1) A scribe is produced from original line maps showing only boundary information. The scribe is then mounted on a drum scanner and from that a scan tape is produced.

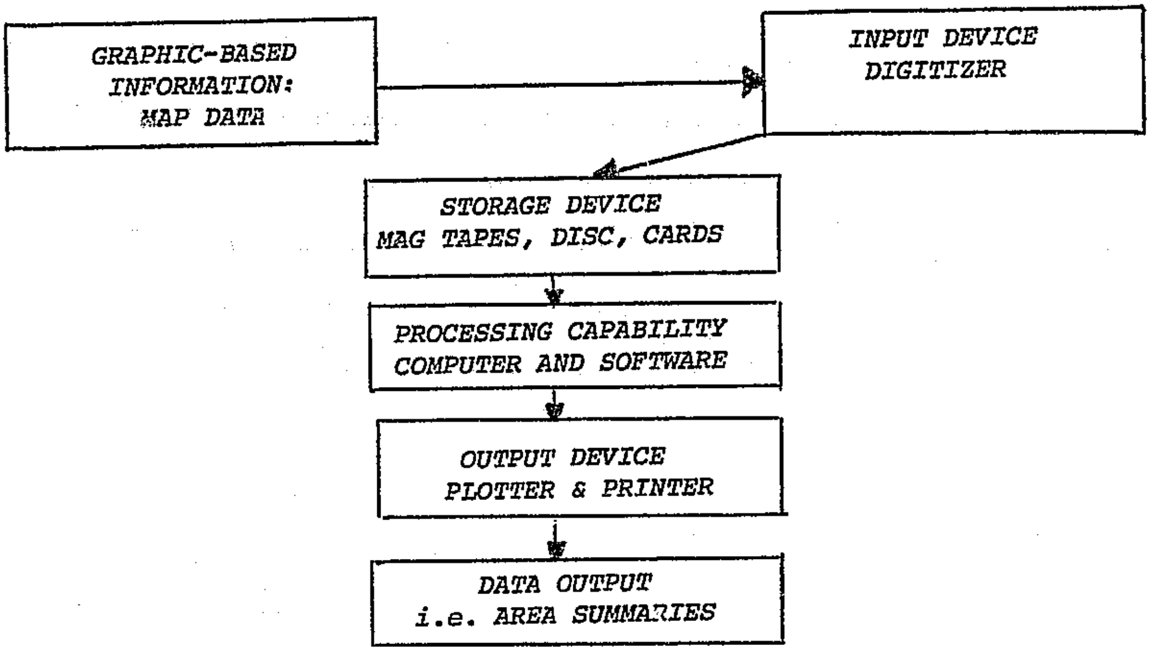


Figure 2-10--Procedural configuration of data handling and analysis

2) From the line map, a numbered overlay is produced. This overlay is simply a sheet of drafting film on which each polygon is given a unique number.

3) The numbered overlay is placed on the scribe and both are placed on the digitizer table. The corner points are digitized as well as one point in each polygon. This produces a digitized tape that is input to the data editing procedures.

4) The numbered overlay and the line map are combined and the classification data are extracted. They are transcribed onto classification data forms that are then keyed to the magnetic tape.

5) The digitizer and encoder data are spooled from several minitapes onto the larger tape. The spool tape is sorted so that the digitizer and classification data for a polygon appear as adjacent records. The output of a sort operation is input to an edit routine.

6) The edit routine performs the normal type of checks on the classification data and checks to see that the digitizer data are valid. It produces two data sets, one containing records of rejected maps and the other containing records of accepted maps. If an error is detected in the map at any point, the entire map is rejected. An error listing is produced for the rejected maps, and corrections are made and input to an update routine, which produces an updated rejected map tape that is again edited. This cycle continues until all maps have been accepted.

7) The accepted maps are input to a compare program that makes use of the second classification tape and the edited tape and compares the records one for one to determine if the classification data have been extracted correctly.

8) All data records are output to a data set organized by map number. A listing is produced indicating those records whose classification data were not identical. The updating procedure at this point is relatively simple requiring a choice of one of the two records. These correction cards are input to another update program that flags the correct record. Once these operations are complete the data are ready for data reduction.

The entire effort seeks to provide the user community with a demonstration of an information system capable of cataloging, inventorying, correlating and analyzing map data. This computer-based approach then provides a powerful tool for the user planning and management function.

For further information concerning the USGS Geography Program's land use interpretation and compilation procedures, see Wiedel and Kleckner, 1975.

CHAPTER 3

LAND USE ANALYSIS

The mapping, measuring, and analyzing of land use, the cornerstone set of activities in the CARETS project model, have consumed a major portion of the project's time and energy. This chapter presents the results of original land use measurements derived from the high-altitude aircraft data base, along with discussion highlighting the significance of such data in analysis of the region's economic and environmental characteristics.

The analysis of land use in the Norfolk test site begins with a discussion of statistical summaries and land use area measurements for the test site. This chapter then discusses the land use changes detected from 1959 to 1970 and presents a more thorough examination of the predominant land uses, trends in land use, and land use change as detected from 1970 to 1972 from high-altitude aircraft photography.

AREA MEASUREMENT AND STATISTICAL SUMMARIES

Land use area summaries and percentages for the Norfolk test site (excluding bays and estuaries) are presented in table 3-1. The same statistics for the four constituent cities (including bays and estuaries) are presented in tables 3-2 and 3-3. With 42.3 percent of the area, forest forms the predominant land use, followed by agriculture with 27.4 percent of the total, urban and built-up with 22.9 percent, nonforested wetlands with 4.4 percent, nonestuarine water with

Table 3-1--Norfolk test site Level II land use summary, 1970*

LAND USE CATEGORY	HECTARES	ACRES	% OF TOTAL
URBAN & BUILT-UP 1	41,276	101,992	22.9
Residential 11	22,066	54,525	12.2
Commercial 12	3,943	9,744	2.2
Industrial 13	1,536	3,795	0.9
Extractive 14	87	214	0.05
Transportation 15	3,049	7,535	1.7
Institutional 16	4,630	11,441	2.6
Strip & Clustered 17 Settlement	1,671	4,129	0.9
Mixed 18	27	66	0.01
Open & Other 19	4,267	10,543	2.4
AGRICULTURAL 2	49,463	122,222	27.4
Cropland & Pasture 21	49,415	122,104	27.4
Orchards 22	35	87	0.02
Feeding Operations 23	13	31	.01
FOREST 4	76,263	188,443	42.3
Forest-Heavy Crown 41 Cover	72,661	179,544	40.3
Forest-Light Crown 42 Cover	3,601	8,899	2.0
WATER (EXCLUDING BAYS & ESTUARIES) 5**	3,988	9,853	2.2
Streams & Waterways 51	1,229	3,036	0.7
Lakes 52	1,444	3,569	0.8
Reservoirs 53	528	1,305	0.3
Other Water 55	786	1,943	0.4
NONFORESTED WETLANDS 6	7,878	19,466	4.4
Wetland (vegetated) 61	7,570	18,704	4.2
Wetland (bare) 62	308	762	0.2

Table 3-1--(continued)

LAND USE CATEGORY	HECTARES	ACRES	% OF TOTAL
BARREN 7	1,434	3,543	.8
Barren (Sand other than beaches) 72	34	83	.02
Barren (beaches) 74	1,374	3,394	.77
Other 75	26	66	0.01
Total Area less Bays and Estuaries	180,302	445,519	100.0
Total Land Area	176,314	435,666	
Bays and Estuaries 54**	18,262	45,125	

*Data derived from CARETS land use maps digitized by the Canada Geographic Information System

**Bay and estuary area summaries lack accuracy due to the inclusion of water areas outside the Norfolk test site.

Table 3-2--Level II land use by cities, Norfolk test site, 1970

	Norfolk		Portsmouth		Virginia Beach		Chesapeake	
	Acres	Hectares	Acres	Hectares	Acres	Hectares	Acres	Hectares
1	33,234	13,450	15,208	6,155	33,609	13,602	19,941	8,070
11	18,664	7,553	9,630	3,897	17,561	7,107	8,670	3,509
12	5,221	2,113	1,518	614	2,186	885	819	331
13	979	396	1,283	519	21	9	1,512	612
14			45	18	169	68		
15	3,142	1,272	662	268	2,401	972	1,330	538
16	2,729	1,104	728	295	5,313	2,150	2,671	1,081
17			270	109	575	233	3,284	1,329
18					66	27		
19	2,499	1,011	1,072	434	5,317	2,152	1,655	670
2	449	182	1,993	807	53,676	21,723	66,104	26,752
21	449	182	1,993	807	53,589	21,687	66,073	26,740
22					87	35		
23							31	13
4	522	211	1,415	573	56,272	22,773	130,234	52,706
41	479	194	864	350	54,102	21,895	124,099	50,223
42	43	17	551	223	2,170	878	6,135	2,483
5	5,734	2,321	8,788	3,557	34,359	13,905	6,097	2,467
51					2,594	1,050	442	179
52	20	8			648	262	2,901	1,174
53	107	43	133	54	871	352	194	79
54	5,607	2,269	6,712	2,716	30,246	12,241	2,560	1,036
55			1,943	786				

Table 3-2--(continued)

	Norfolk Acres	Norfolk Hectares	Portsmouth Acres	Portsmouth Hectares	Virginia Beach Acres	Virginia Beach Hectares	Chesapeake Acres	Chesapeake Hectares
6	413	167	1,047	424	15,132	6,124	2,874	1,163
61	413	167	370	150	15,132	6,124	2,789	1,129
62			677	274			85	34
7					3,543	1,434		
72					83	34		
74					3,394	1,374		
75					66	27		
TOTAL AREA	40,352	16,330	28,451	11,514	196,591	79,560	225,250	91,159

Table 3-3--Percentages of 1970 land use by land use category

Land uses	Norfolk	Portsmouth	Virginia Beach	Chesapeake
1 URBAN	82.4	53.5	17.1	8.9
11 Residential	46.3	33.8	8.9	3.8
12 Commercial	12.9	5.3	1.1	0.4
13 Industrial	2.4	4.5	.01	0.7
14 Extractive		0.2	.08	
15 Transportation	7.8	2.3	1.2	0.6
16 Institutional	6.8	2.6	2.7	1.2
17 Strip & cluster		0.9	0.3	1.5
18 Mixed			.03	
19 Open & other	6.2	3.8	2.7	0.7
2 AGRICULTURAL	1.1	7.0	27.3	29.3
21 Cropland & pasture	1.1	7.0	27.3	29.3
22 Orchards			.04	
23 Feeding operations				.01
4 FOREST	1.3	5.0	28.6	57.8
41 Heavy crown cover	1.2	3.0	27.5	55.1
42 Light crown cover	0.1	1.9	1.1	2.7
5 WATER	14.2	30.9	17.5	2.7
51 Streams & waterways			1.3	0.2
52 Natural lakes	.05		0.3	1.3
53 Reservoirs	0.3	0.5	0.4	.09
54 Bays & estuaries	13.9	23.6	15.4	1.1
55 Other		6.8		
6 NONFORESTED WETLANDS	1.0	3.7	7.7	1.3
61 Vegetated	1.0	1.3	7.7	1.2
62 Bare		2.4		.04
7 BARREN LAND			1.8	
72 Sand other than beaches			.04	
74 Beach			1.7	
75 Other			0.3	

Source: CARETS 1970 Virginia Beach and Norfolk land use sheets as digitized by Canada Geographic Information System.

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2.2 percent, and barren lands (mostly beach and dunes) with 0.8 percent. Within the Norfolk test site as a whole, a great amount of rural or open land still exists to accommodate urban expansion.

A somewhat different picture, however, is presented within the four separate cities shown in tables 3-2 and 3-3. The land use in Norfolk is 82.4 percent urban, with comparatively small amounts of forest or agricultural lands. Partially as a result of the 1968 annexation of land from Chesapeake, Portsmouth has only 53.5 percent of its territory in urban uses, 30.9 percent in water bodies (which provide some potential for expansion in the form of fill operations), and only 7 percent and 5 percent respectively in agriculture and forest land. Chesapeake, the largest and least populated of the test site cities, has 91.1 percent of its land in nonurban uses, 29.3 percent in agriculture and 57.8 percent in forest. Finally, Virginia Beach has 17.1 percent of its land in urban uses (amounting to 20.2 percent if bays and estuaries are excluded). Agricultural land comprises 27.3 percent of the total; forest, 28.6 percent; wetlands, 7.7 percent; and bays and estuaries, 15.4 percent.

The statistical summaries used in the analysis of land use and land use change in the Norfolk test site have been derived from various sources. The same political jurisdictions, therefore, may have different area values, depending on the source. Part of the data compiled and processed by the Geography Program has been digitized by the Canada Geographic Information System, which has developed the capability to overlay and retrieve multiple data sets. Investigators have applied the "polygon" method of measuring the entire areas of the land use faces as mapped rather than the "grid cell" approach by which the predominant land use of a certain sized grid cell is assigned to the entire area of the cell.

For the entire Norfolk test site, researchers overlaid the maps of Level II land use with those of census tracts. The resulting land use area summaries by census tract are presented in appendix E. Although investigators have not tested the accuracy of the digitized statistics, the figures thus derived for political areas are close to those published by the U.S. Bureau of the Census (1973) and presented in table 3-4. Differences are probably best explained by the existence of water bodies, parts of which may or may not be counted as part of the land area.

Limited access to digitizing facilities has forced the CARETS project to use another means of area measurements for some purposes: the dot grid or dot planimeter. This is a sampling method operationally simpler and perhaps faster than the polar planimeter and grid planimeter; the dot planimeter is theoretically accurate, but the size and shape of the area being measured affect the accuracy of the measurement. The larger and more compact the area measured, the more accurate the measurement is likely to be. One study of dot planimeter measurement revealed that a minimum of 100 points or dots per area is necessary to result in an accuracy of approximately 1.5 percent deviation from the true area (Yuill, 1970). Many of the polygons measured by dot planimeter were smaller than 100 dots (1,000 acres or 400 ha), and such measurements may be considerably less accurate than that accomplished by digitizer. It is also likely that land uses occupying more extensive areas will be more accurately counted than those for smaller areas. In this report, 1970 Level

Table 3-4--Population and land area, Norfolk test site

	Population		Land area				
	1970 Census	% of test site	km^2	mi^2	Hectares	Acres	% of test site
Norfolk	307,951	45	137	53	13,727	33,920	8
Portsmouth	110,963	16	75	29	7,511	18,560	4
Chesapeake	89,580	13	883	341	88,322	218,240	50
Vir..nia Beach	172,106	25	671	259	67,083	165,760	38
TOTAL TEST SITE (1970 SMSA)	680,600	99*	1,766	682	176,643	436,480	100

*Total does not equal 100 because of rounding.

Source: U.S. Bureau of the Census, 1973.

II land use data derived from aerial photography and 1972 Level I LANDSAT derived land use data have been digitized and measured automatically, as have 1970-72 land use change areas. Land use change from 1959 to 1970, however, has been measured manually by dot planimeter.

LAND USE CHANGE TRENDS, 1959-70

As in most areas under the influence of urbanization, the Norfolk test site has undergone and is undergoing significant and extensive changes in land use. Tables 3-5 and 3-6 provide an overview of the Level I land use change within the study area between 1959 and 1970. Of the 184 km^2 of change detected, nearly 90 percent occurred in only four sets of changes: 43.5 percent of land use change involved conversion from agricultural to urban land use, 18.5 percent from forest land to urban, 17.9 percent from forest to agriculture, and 10.3 percent from agriculture to forest. In all, 9.6 percent of the area in the Norfolk test site changed from one Level I land use category to another. No doubt this percentage would be much higher if one considered changes within a Level I category, as from one urban land use to another.

Figures 3-1 and 3-2 reveal the location of areas of change detected for the 11-year period. The greatest areas of no Level I change are in the urban cores of Norfolk and Portsmouth, where change that has occurred has been from one urban and built-up use to another. Only 3 km^2 or 1.63 percent of the total change detected was from urban to nonurban uses.

Table 3-5--Norfolk-Portsmouth SMSA land use change Level I 1959-70
(in km^2 derived by dot count)

Land Use in 1959	Land Use in 1970					
	URBAN (1)	AGRICULTURE (2)	FOREST (4)	WATER (5)	WETLAND (6)	TOTAL (1959)
URBAN (1)		2	1			3
AGRICULTURE (2)	80		19	1		100
FOREST (4)	34	32		2	2	70
WATER (5)					3	3
WETLAND (6)	2	1	5			8
TOTAL (1970)	116	35	25	3	5	184

Table 3-6--Percentage* of 1959-70 land use change in Level I categories

Percentage of total change to 1970 land uses

Percentage of total change from 1959 land uses

	URBAN	AGRICULTURE	FOREST	WATER	WETLAND	TOTAL
URBAN		1.1	.5			1.6
AGRICULTURE	43.5		10.3	.5		54.3
FOREST	18.5	17.4		1.1	1.1	38.1
WATER					1.6	1.6
WETLAND	1.1	.5	2.7			4.3
TOTAL	63.1	19.0	13.5	1.6	2.7	99.9

*Percentages rounded to the nearest .1 percent

Areas of Level I Land Use Change, 1959-1970

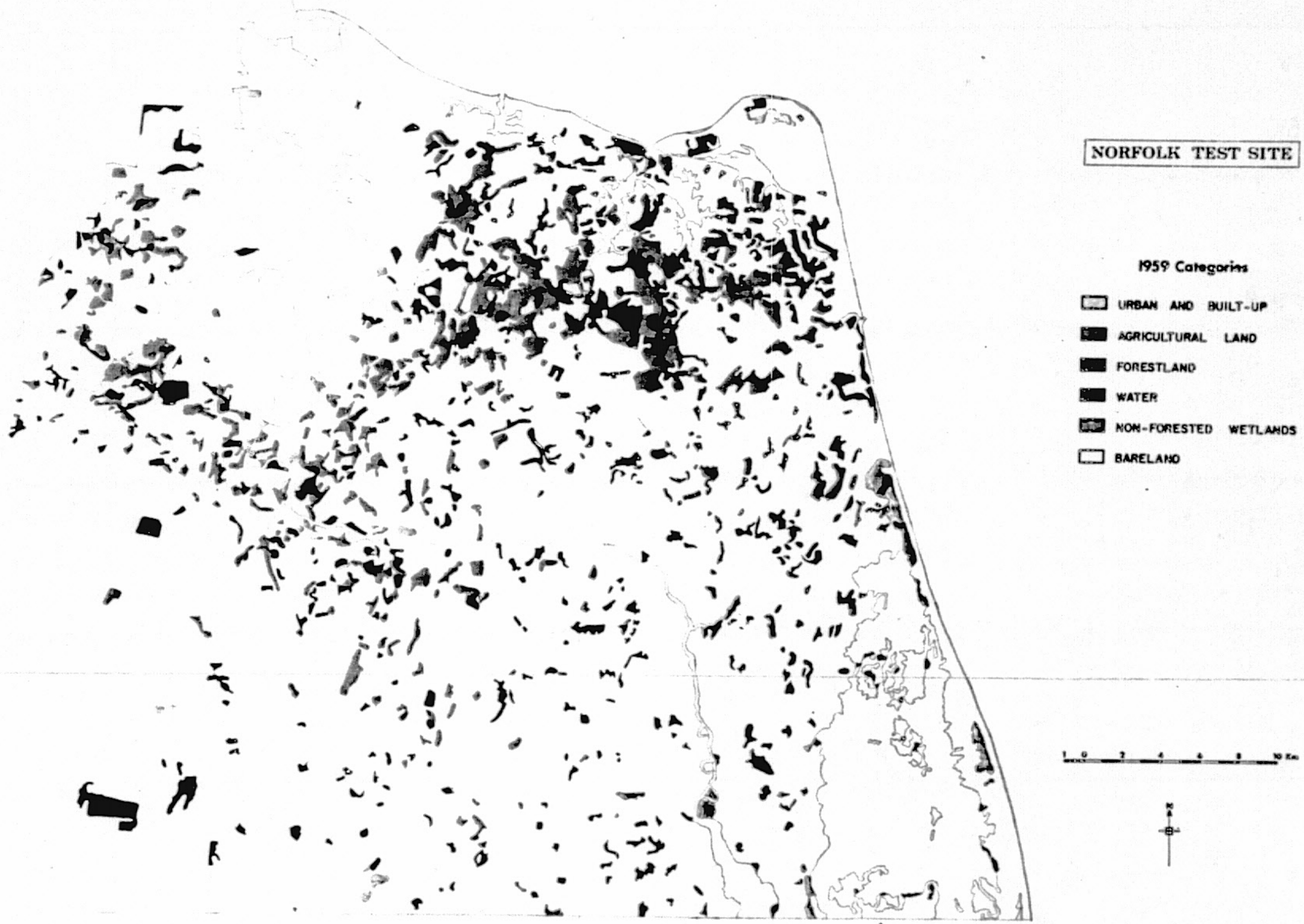


Figure 3-1--This map depicts areas for which Level I land use change occurred in the period 1959-1970.
EDC-010107.

Areas of Level I Land Use Change, 1959-1970

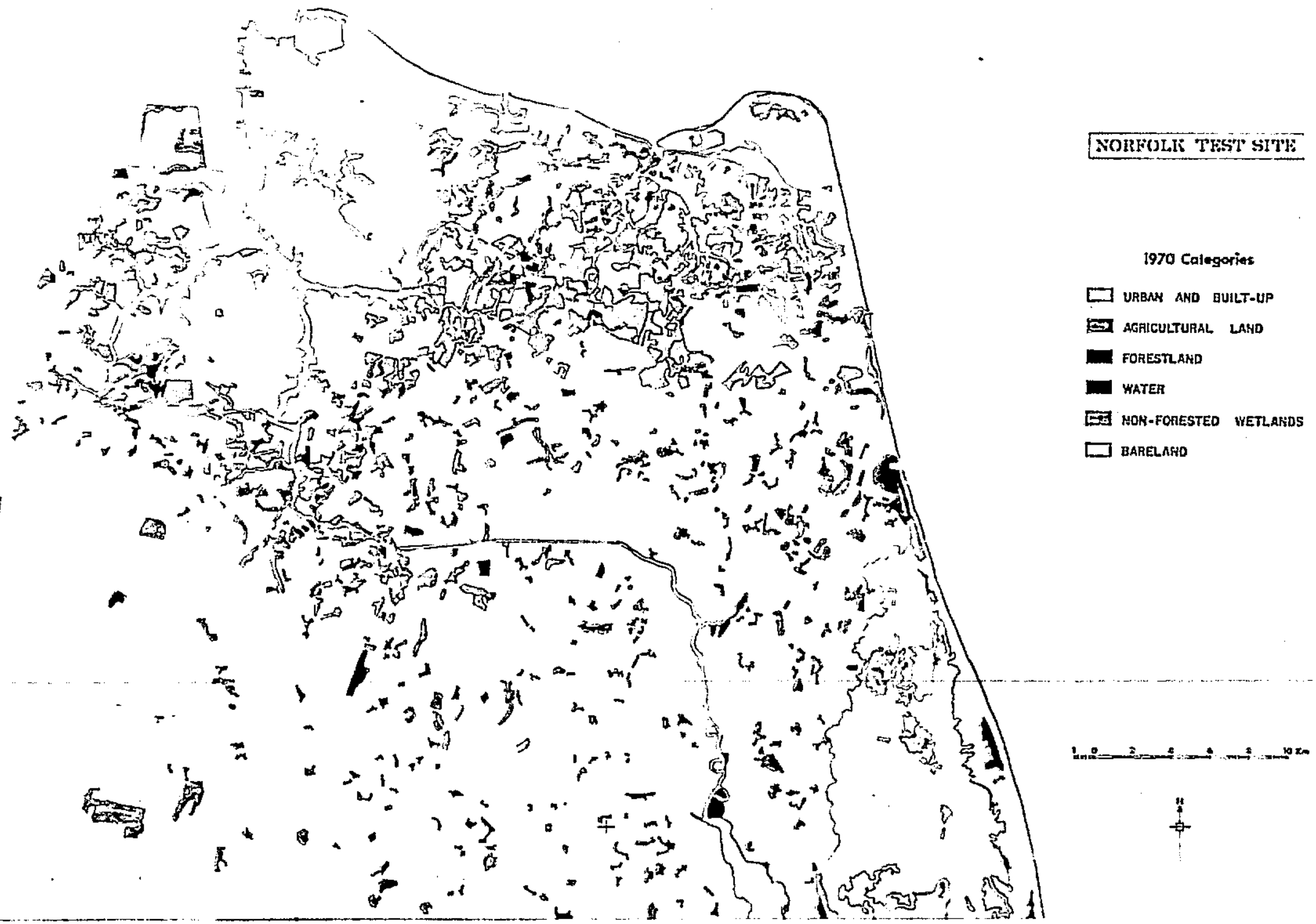


Figure 3-2--This map depicts areas for which Level I land use change occurred in the period 1959-1970.
EDC-010108.

The change from agricultural and forest to urban land uses, 62 percent of all change, has occurred to the greatest extent within the areas comprising Virginia Beach and Portsmouth. Much of this change has been to residential and commercial uses and reflects the population increases of the 1960's.

The change from forest land to agriculture exceeded the change from agriculture to forest land by 13 km^2. These changes occurred predominately in the southern rural half of the study area. In the southwest corner of Chesapeake, land use changes to and from forest and agriculture were the only changes detected. Foresting operations and drainage of land in the Dismal Swamp can be readily detected as can the scattered clearing of land for agriculture and the afforestation of abandoned fields.

Some of the 3-km^2 change from water to wetlands may actually be "false change." Tidal or salt marshes may be extremely difficult to delineate due to changes in their appearance on photography taken at different tidal stages. Such change detection that has not been field checked may be suspect.

The greater part of the water to wetlands change consists of the Craney Island Disposal Area, a rhomboidal-shaped area extending out into Hampton Roads, used for dumping of spoils from channel dredging in the harbor. Operated by the U.S. Army Corps of Engineers, the Craney Island construction project was begun in 1954 as an extension of the existing Craney Island, a previously filled area which is the site of the U.S. Naval Fuel Depot. Before construction could begin, the Federal Government had to obtain title to all the submerged land to be filled, including leased and public oyster bottoms and the right, if necessary, to dredge bottomland on the south shore of Hampton Roads with compensation for oyster growers losing crops as a result. By 1957, the levees, 2.5 m above mean sea level, surrounding the Craney Island site were completed and the pumping of substantial amounts of dredge spoils behind the levees began. The 1,012-ha area is predicted to be filled by 1978, but the fill area is not expected to be ready for intensive use until 1985. The eventual use of the area is unknown, although the Virginia Division of State Planning and Community Affairs has drafted two alternate plans for the area. One plan calls for mixed industrial, commercial, residential and industrial uses, whereas the other proposes the construction of an airport, port facilities and a recreational area. The amount of bare wetlands detected in 1970 represents the progress of the project to that time (Virginia Division of State Planning and Community Affairs, 1971a).

Extensive land filling operations have been conducted in the Norfolk-Portsmouth harbor throughout the 20th Century. Between 1955 and 1965, the 37-ha site of the Portsmouth Marine Terminal was filled from material dug in the construction of the Midtown Tunnel connecting Norfolk and Portsmouth. An additional 14 ha of land will be created by the filling of the water between the finger piers immediately upstream on the Elizabeth River from the Portsmouth Marine Terminal. Another fill operation is planned for Norfolk, which will create land for the Norfolk International Terminal.

A final land use change detected during the period from 1959 to 1970 was the change from nonforested wetland to forest in the Back Bay area of Virginia Beach. Nearly surrounding Back Bay is a fringe of coastal marsh, part of which lies adjacent to the barrier beach, protecting the bay from the Atlantic. High tides and high waves result in oceanic overwash carrying sand over the dunes and depositing it into the marshland, eventually creating new dry land. By this process, the barrier beach moves westward and along with it the vegetation succession on the overwash terrace, from low salt marsh to high salt marsh to scrub and closed grassland. The development of shrub forest in the former high salt marsh might well explain the land use change from wetland to forest (Dolan and others, 1973). Man's stabilization of dunes along this barrier beach, however, has greatly restricted overwash and thus the overwash phenomenon may not adequately explain the detected change.

LAND USE 1970

Urban and Built-Up Land Use
(Classification category 1, Level I)

Urban and built-up land in the Norfolk study area comprises 41,276 ha (101,992 acres) or 22.9 percent of the total area. The variation in urban land use is considerable as shown in tables 3-2 and 3-3. For 1970, in absolute urban area, Virginia Beach ranked highest among the four test site cities with 13,602 ha (33,609 acres) followed closely by Norfolk with 13,450 ha (33,234 acres). Portsmouth was found to have 6,155 ha (15,208 acres) of urbanized land, and Chesapeake, 8,070 ha (19,941 acres). Figure 3-3 presents the urbanized portion of the Norfolk test site which is defined by the U.S. Bureau of the Census as

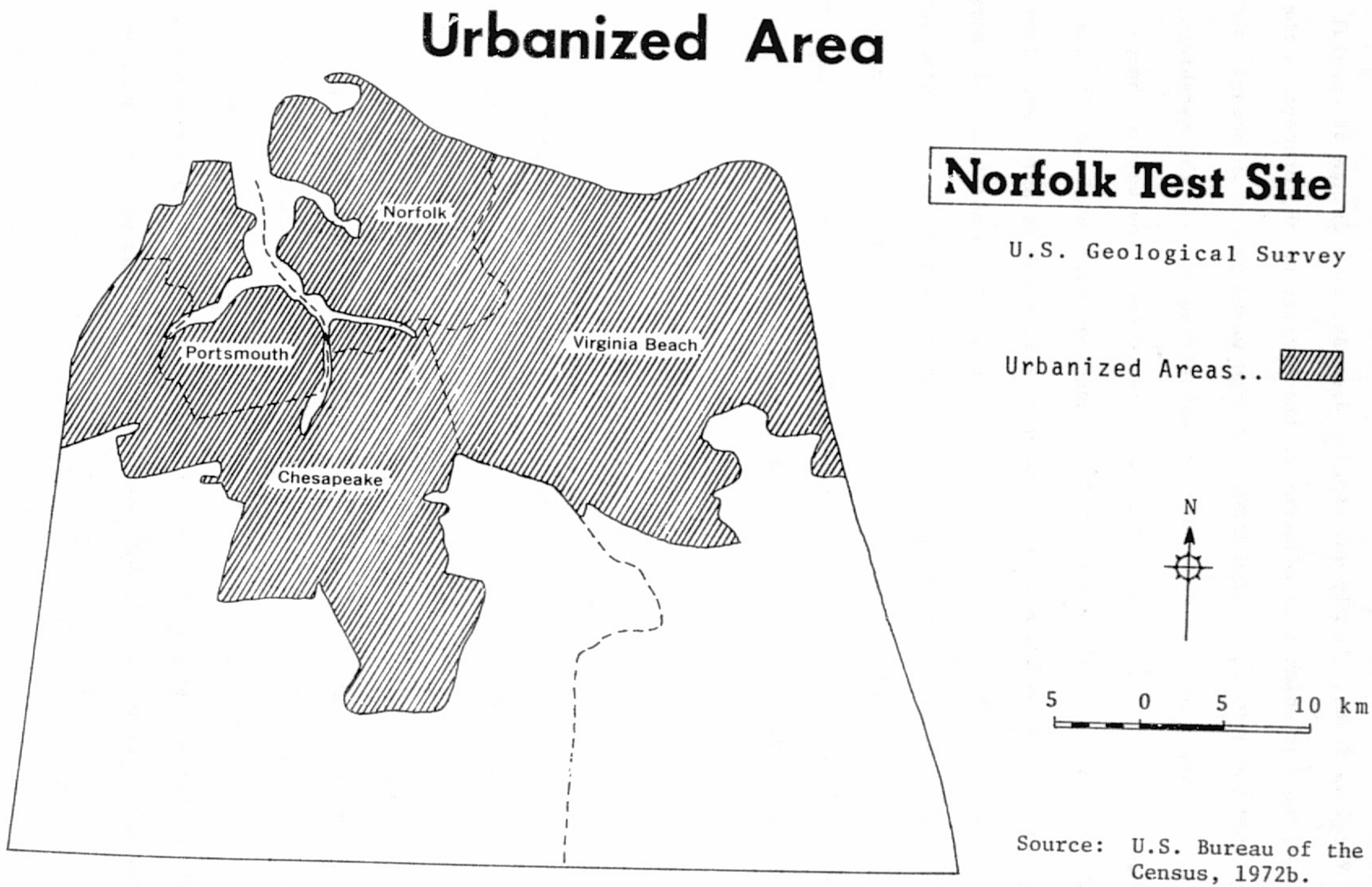

Urbanized Area
Norfolk Test Site
U.S. Geological Survey
Urbanized Areas..
N
5 0 5 10 km
Norfolk
Portsmouth
Virginia Beach
Chesapeake
Source: U.S. Bureau of the Census, 1972b.

Figure 3-3

an area consisting of a central city, or cities, and surrounding closely settled territory (U.S. Bureau of the Census, 1972). According to the CARETS land use map, Norfolk's urban land uses comprise 82.4 percent of the city's total area, Portsmouth 53.5 percent, Virginia Beach 17.1 percent, and Chesapeake 8.9 percent. None of these data sets, however, reflect the total picture of urbanization in the study area. The separate urban land uses must be examined and related to the whole.

Residential Land Use
(Classification category 11, Level II)

Residential land use is by far the most extensive and ubiquitous. For all cities except Chesapeake, more than half the urban area is in residential use. The less urbanized the city within the Norfolk test site, the greater the percentage of residential land use within its urbanized territory. If "strip and cluster" land use (Circular 671, Level II Category 17, most of which is generally residential in nature) were reclassified as residential for Chesapeake, that city's residential area would exceed 60 percent of its urban and built-up area.

The nature of residential areas, however, also varies extensively among the different cities of the Norfolk test site. Table 3-7 displays net density (persons per residential acre) for the constituent cities in 1965 and projections into the future. Norfolk's housing has the greatest density, followed by Portsmouth, Virginia Beach and Chesapeake. As the source for the 1970 residential area summaries on table 3-1, the CARETS land use maps reveal a considerably greater residential area and lower density than the figures provided by Southeast Virginia Planning

Table 3-7--Projected residential areas and densities for Norfolk test site (1965-85)

Net Density	Chesapeake	Norfolk	Portsmouth	Virginia Beach	SMSA Area
Persons/res. acre-1965	7.5	25.3	17.8	11.2	15.4
PROJECTED:					
1970	7.7	25.5	17.8	12.1	15.7
1975	8.0	25.8	17.8	13.1	16.1
1980	8.3	26.2	18.4	14.2	16.7
1985	8.6	26.7	19.0	15.3	17.4
RESIDENTIAL AREA IN ACRES*:					
1965	10,836	12,421	7,148	12,702	43,107
1975	16,195	13,187	7,411	15,718	52,511
1985	21,254	13,988	7,708	20,337	63,287
RESIDENTIAL AREA INCREASE:					
1965-75	5,359	766	263	3,016	9,404
1975-85	5,059	801	297	4,619	10,776

* 1 acre = .405 hectares

Source: Southeast Virginia Planning District Commission, 1972.

District Commission (1972) in all cities, except Chesapeake. For Chesapeake, the 1970 density is approximately the same as that reported for 1965 and its area is between that reported for 1965 and that predicted for 1975. The discrepancy may lie in the amount of residential land projected for the year 1970.

To understand the present residential land use in the Norfolk test site, a knowledge of the growth and development of residential land within the most densely populated areas can be of great value. Early settlement in Norfolk occurred near the harbor at the juncture of the Elizabeth River and Eastern Branch in the present downtown area. The city's rate of growth in area was fairly slow. In 1874, when Norfolk became a city, its area included 3.4 km^2 (1.3 mi^2) and it had a population of over 10,000. Through annexation of territory to the north in 1890, 1902, 1906, and 1911, the land area of the city increased to 23.3 km^2 (9 mi^2) and included most of the peninsula between the Lafayette and Elizabeth Rivers. With the increased population resulting from wartime activities in the city, Norfolk accomplished its largest annexation of 59.6 km^2 (23 mi^2) and all of its western half in 1923 (Norfolk City Planning Commission, 1967). The greatest rapid increase in housing occurred in the World War II years (1940-1945) when dwelling units in the city increased from 38,753 to 48,067. Some of the increased population spilled across the corporate limits; and in the Tanners Creek and Washington areas, the number of dwelling units increased from 3,699 in 1940 to 11,411 in 1946. To accommodate the increased population, temporary public housing projects were constructed. After the war, much of the temporary housing remained because it was occupied to capacity and no adequate housing existed to replace it (University of Virginia, 1947). Encouraged by Federally-guaranteed mortgages and improved highways, a post-war housing construction boom spread residences further eastward into Princess Anne County. In 1955, Norfolk annexed additional territory to the east, and in 1959 it annexed its last territory to bring it to its present size. Between 1950 and 1960, Norfolk's population increased by 91,000.

Taking advantage of the 1949 Federal Housing Act, Norfolk became one of the early cities to initiate a redevelopment program to replace 485 acres of urban blight, much of it residential slums. The first phase began in 1951 with the replacing of inner city delapidated housing dating back to the 19th century. Another phase began in 1958 and involved the renewal of the downtown area, including the construction of a new civic center (Norfolk Redevelopment and Housing Authority, 1960). In 1960, Norfolk had 5,296 units of public housing (Norfolk Redevelopment and Housing Authority, 1967).

Yet the problem of blighted housing is still present. The Model Cities residential areas of Berkely, Brambleton, Hunterville, and Ghent with 11.9 percent of Norfolk's population and 7.1 percent of its area have one and two story, single and multiple family dwellings. Ninety-two percent are older than 25 years, and a majority were constructed in the 19th century. Among the physical problems of these residential areas are narrow streets, inadequate parking, poor traffic conditions, poor lighting, lack of open recreation space, and poor surface drainage.

The development of residential areas in Portsmouth directly parallels that of Norfolk with the similar response of annexation when population reached beyond its corporate limits. The original settlement, as in Norfolk, occurred in the present downtown area, directly across the Elizabeth River from Norfolk, along and back from the waterfront. The Naval Shipyard was established south of the original settlement, but did not become a part of the city until the 1960 annexation. In 1894, territory along the Elizabeth River, north of the original settlement, was annexed, and World War I encouraged the growth of housing, which resulted in a 1919 annexation of land west of the city. Portsmouth's population grew from 26,000 in 1910 to 51,000 in 1917 to an estimated 57,000 in 1918 (City of Portsmouth, 1968). By 1928, a wide range of new housing had developed surrounding the urban core and the Naval Shipyard.

World War II and the expansion of naval activities resulted in the initiation of one of the country's first public housing developments where thousands of publicly financed temporary housing units were constructed. Twenty-two thousand of these units remained occupied following the war. "The overall effect of this 'war impact' was to create an 'overused' high density core residential area, which was to be separated and divided from future suburban middle class neighborhoods by a wall of temporary wartime housing and other governmental actions" (City of Portsmouth, 1968).

The housing boom continued following the war, with the growth of middle class suburban residences to the west, including the replacement of some of the temporary housing. The annexation of 1960 doubled the area of Portsmouth, yet the city was still very densely populated. After 1960, the supply of new housing grew slowly. More housing was constructed west of the city in Norfolk County, and part of this area of growth was annexed in 1968.

The housing problems of Portsmouth's inner city are numerous. Although the northern part of this area is being revitalized, its eastern part is an area of extensive blight. It has poor housing, heavy traffic, and the Navy Yard isolates it from the rest of the city. Other problems include narrow streets, narrow lots, no off-street parking, owner neglect, obsolescence, hasty wartime conversion to multiple-family use, and debris-filled vacant lots and open ditches (city of Portsmouth, 1968, p. 37).

The growth of residential areas and to some extent the condition of housing throughout the urbanized portion of the Norfolk test site are reflected in table 3-8, which reveals the ages of housing. For Norfolk and Portsmouth, the greatest period of housing growth occurred from 1940 to 1959, whereas that for Virginia Beach and Chesapeake occurred from 1950 to 1970.

An overall picture of housing and occupancy of housing units in 1970 is displayed in table 3-9. From this table, one can conclude that most year-round structures are owner-occupied, single-unit residences that do not lack plumbing facilities. The greatest amount of multiple-unit residences with 10 or more units are in Norfolk and Virginia Beach, and

Table 3-8--Age of housing in the urbanized portion of the Norfolk test site

Date Constructed	Number of all year-round housing units built			
	Norfolk	Portsmouth	Virginia Beach (urban part)	Chesapeake (urban part)
1969-March 1970	1,615	754	3,122	966
1965-68	6,074	2,217	10,176	4,169
1960-64	8,213	3,543	13,375	5,372
1950-59	24,967	8,921	13,676	7,463
1940-49	22,318	10,538	3,845	3,453
Before 1940	27,802	10,496	3,270	4,410
TOTAL	90,989	36,469	47,464	25,863

Source: U.S. Bureau of the Census, 1972b

Table 3-9—Norfolk test site 1970 housing and occupancy characteristics

City	Percentage of total population				Year-round housing units	Units lacking some or all plumbing	Units in		Owner occupied units	Renter occupied units
	Negro	In group quarters	Under 18	62 and older			1 unit structures	10 or more unit structures		
Norfolk	28	15	31	9	91,000	1,949	49,929	5,354	37,193	423
Portsmouth	40	2	36	10	36,466	1,254	25,585	681	19,078	308
Virginia Beach	9	7	39	5	47,393	1,845	27,256	1,124	30,865	975
Chesapeake	23	1	39	8	25,861	1,710	21,806	145	18,098	838

Source: U.S. Bureau of the Census, 1972b the greatest amount of renter-occupied housing exists in Chesapeake and Virginia Beach. Many of the multiple-unit housing structures in Norfolk and Portsmouth are owner-occupied row houses; Virginia Beach possesses a greater number of more recently constructed rented apartment units.

The condition of housing in the Norfolk test site is presented in table 3-10. Not available in the 1970 Census of Housing, these data show not only the amount and condition of urban housing but also that of rural areas. These rural conditions are best represented by the figures for Norfolk and Princess Anne Counties. Although the city of Norfolk had more delapidated and deteriorating housing than any other political jurisdictions, rural Princess Anne (9.1 percent) and Norfolk (5.6 percent) Counties exceeded the city of Norfolk (3.9 percent) in their percentages of delapidated housing. Portsmouth and Norfolk led the study area in percentage of deteriorating housing with 15.14 percent and 12.75 percent, respectively. Since 1960, urban renewal programs have eliminated some of the worst housing, but the remaining housing in poor condition, both urban and rural, is a serious problem.

On-base military residences in the test site comprise a total of 10,140 housing units. Table 3-11 shows the breakdown of housing units by military bases. More than half of these units are located on Ft. Story Army Base, and over 30 percent are on two naval bases. An additional 600 units of housing are presently under construction at Little Creek Naval Amphibious Base in Virginia Beach.

Closely associated with military bases and transient populations are mobile homes. The number of mobile home units, as reported in the 1970

Table 3-10--Dwelling unit analysis - 1960

		SOUND				DETERIORATING				DILAPIDATED
	TOTAL DWELLING UNITS	TOTAL	With all plumbing facilities	Lacking only hot water	Lacking other plumbing facilities	TOTAL	With all Plumbing Facilities	Lacking only hot water	Lacking other plumbing facilities	TOTAL
Norfolk	87,555	72,930	69,397	841	2,692	11,169	7,322	1,017	2,830	3,456
Portsmouth	33,349	27,171	25,576	521	1,074	5,051	3,112	488	1,451	1,127
South Norfolk	7,167	5,166	4,824	40	302	1,326	898	59	369	675
Virginia Beach	25,279	21,307	20,477	94	733	2,317	1,254	105	958	1,255
Chesapeake	31,088	14,264	12,543	136	1,285	2,317	880	173	1,264	1,452
Norfolk County*	13,921	10,936	9,712	301	923	1,721	666	64	991	1,264
Princess Anne County**	21,268	14,264	12,543	136	1,285	2,317	880	173	1,264	1,452
TOTAL	179,631	146,619	136,164	2,081	8,374	23,931	13,680	1,907	8,344	9,081

*Norfolk county merged with the city of South Norfolk to form the city of Chesapeake in 1963.

**Princess Anne County merged with city of Virginia Beach in 1963.

Source: U.S. Bureau of the Census, 1961.

Table 3-11--Military housing in the Norfolk test site, 1972

LOCATION	HOUSING UNITS
NORFOLK	
Sewell Point Naval Station	2,162
VIRGINIA BEACH	
Oceana Naval Air Station	534
Little Creek Naval Amphibious Base	1,032
Fort Story	5,564
Camp Pendleton	600
Dam Neck Naval Weapons Training Facility	41
PORTSMOUTH	
Naval Shipyard	170
Naval Hospital	19
CHESAPEAKE	
St. Julian Creek Ammunition Depot	18
TOTAL	10,140

Source: Southeart Virginia Regional Planning District Commission (from information derived from 5th Naval District Naval Facilities Command)

Census of Housing, are: Norfolk - 950 units, Portsmouth - 133 units, Virginia Beach - 1,644 units, and Chesapeake - 1,064 units. Virginia Beach dominates this category, not only because of its large transient military population, but also for its position as a major ocean resort.

Clearly the Level II category "residential land use" is not sufficient in detail to describe many of the characteristics of residential land mentioned above which represent critical data needs in urban planning and management. Some of the more detailed information, for example single versus multiple-family dwellings, dwelling unit density, and housing quality, could be added by more detailed analysis of remote sensing source materials, carried to Level III, Level IV, or beyond.

Commercial and Industrial Land Use
(Classification categories 12 and 13, Level II)

Commercial and industrial land use in the Norfolk test site will be discussed jointly. Although the commercial and service category (12) covers a broad range of economic activities, these are very often related closely both geographically and economically to industrial enterprises. Both types of land use comprise relatively small proportions of the total test site: commercial--3,943 ha (9,744 acres) or 2.2 percent of total area; and industrial--1,536 ha (3,795 acres) or 0.9 percent of the total land area.

Among the separate cities, Norfolk was found to have over twice as much land devoted to commercial and service use, 2,113 ha (5,221 acres) or 12.9 percent of its total area, as its closest competitor, Virginia Beach, with 885 ha (2,186 acres) or 1.1 percent of its total area.

Portsmouth has 5.3 percent of its land in commercial uses, but only 614 ha (1,518 acres), and Chesapeake has 331 ha (819 acres) or 0.4 percent of its total area in commercial land uses.

The greatest concentrations of commercial property occur in the central business districts of Norfolk and Portsmouth with the older established retail and business centers. The Norfolk central business district was reported to have 65,928 m^2 (709,668 ft^2) of retail floor space, and downtown Portsmouth, 34,898 m^2 (375,654 ft^2) of the same (Southeastern Virginia Planning District Commission, 1962). The Virginia Beach central business district is much smaller and is elongated along Atlantic Avenue, parallel to the ocean. This area thrives from both the resort business in the summer and that generated by the local population in the off season. This area also prospers from the other resort-related businesses, including hotels, motels, restaurants, and recreation.

With the extensive suburbanization of the Norfolk test site and the establishing of shopping centers readily accessible to suburban populations, the central business districts have had to struggle in the attempt to maintain business. The Norfolk and Portsmouth central business districts thrived during World War II, but following the war the basic problems of these areas became manifest. In Norfolk, the downtown area was in a serious state of blight, being both rundown and inaccessible. An urban renewal program was initiated that cured many of the downtown areas' ills and that has made the downtown retail area more accessible and more desirable.

The growth of shopping centers has accompanied the suburbanization process and reflects rapid residential growth in recent years. The earliest shopping center in the Norfolk area was constructed in the mid-1940's, and though a congested shopping area today, it continues to produce high retail sales. The greatest number of shopping centers are located in Norfolk, Portsmouth, and Virginia Beach at the intersections of major highways.

Five regional shopping centers, 11 community centers, and 64 neighborhood shopping centers were reported for the Norfolk test site in January, 1972 (Virginia-Pilot and Ledger Star & Southeastern Virginia Planning District Commission, 1972). Of the five regional centers, three were in Norfolk, one in Virginia Beach, and another in Portsmouth. All except one were planned centers which opened and had significant additions after 1959. Of the smaller community shopping centers, four were in Norfolk, three in Portsmouth, three in Chesapeake, and one in Virginia Beach. One of these opened as early as 1957; six opened between 1960 and 1963; and the remaining four opened after 1967.

Sixty-four neighborhood and special interest facilities were reported for the test site, 30 in Norfolk, 19 in Virginia Beach, 9 in Chesapeake, and 6 in Portsmouth. The great majority of those in Norfolk and Portsmouth opened during the 1950's, though in Chesapeake and Virginia Beach all but 3 of 28 centers opened in 1959 or later.

During 1972 and 1973, 10 new shopping centers were scheduled to open, 1 regional center, 6 community centers, and 3 neighborhood centers. Of these 10, 7 were in Virginia Beach, 2 in Portsmouth and 1 in Chesapeake.

Approximately 164,800 persons were employed in commercial and service activities in the Norfolk region (including Nansemond County and the city of Suffolk) in 1970. This number is not as large as that of most metropolitan areas relative to basic employment because the Norfolk area's large military population consists of more single people and less family groups than an equally sized civilian population. Military employees generally have smaller incomes and obtain many of their services and do much of their shopping at military base commissaries and exchanges of which the area has a total of 18 (Virginia Division of State Planning and Community Affairs, 1971b).

The growth forecast for commercial and service land use between 1975 and 1985 in the Norfolk study area is shown in table 3-12. Virginia Beach and Chesapeake are expected to experience an increase of nearly 280 ha (691 acres), whereas Norfolk and Porthsmouth's commercial land use is expected to increase by only 115 and 50 ha, respectively. As population growth continues within northern Virginia Beach and Chesapeake, an increase in commercial land use will meet the increasing demands for goods and services.

The recent trend in wholesale commercial land use as well as industrial (particularly light industrial) has been to locate in suburban areas near major highways and railroad lines and in concentrations within specially zoned industrial parks where utility requirements can be met. These parks may consist entirely of either warehousing or industrial enterprises, but often they contain a mixture of the two. These areas are easily identifiable from high-altitude photography, but the

Table 3-12--Commercial and industrial land use forecast for the Norfolk test site

DATE	NORFOLK		PORTSMOUTH		VIRGINIA BEACH		CHESAPEAKE		TOTAL	
	Hectares	Acres	Hectares	Acres	Hectares	Acres	Hectares	Acres	Hectares	Acres
					COMMERCIAL LAND USE					
1975	1,046	2,585	275	680	533	1,317	556	1,374	2,265	5,597
1985	1,161	2,869	326	806	842	2,081	833	2,058	3,161	7,811
1975-85	115	284	50	124	279	689	276	682	751	1,856
					INDUSTRIAL LAND USE					
1975	1,478	3,652	470	1,161	469	1,159	2,071	5,117	4,487	11,087
1985	1,614	3,988	561	1,386	723	1,787	2,559	6,323	5,457	13,484
1975-85	136	336	92	227	253	625	488	1,206	969	2,394

Source: Southeast Virginia Planning District Commission, 1969a differentiation between industrial and commercial use is extremely difficult. In most cases industrial parks have been classified as commercial and services (12). Category areas field checked and found to be industrial, however, were so classified.

Industrial land occupies considerably less area than commercial land in the Norfolk test site. The CARETS 1970 land use map of the Norfolk area reveals that Portsmouth has the greatest amount of industrial land with 1,519 ha (1,283 acres) or 4.5 percent of its total area. Of this, however, 307 ha (758 acres) comprise the Portsmouth Naval Shipyard, which is engaged in industrial activities. Industrial land use in Norfolk amounts to 396 ha (979 acres), which is exceeded by Chesapeake's 612 ha (1,512 acres). Virginia Beach has only 9 ha (21 acres) of industrial land use.

Industry has not played a large role as employer in the Norfolk test site. In fact, in 1970 only 24,774 persons were engaged in manufacturing, approximately 3.4 percent of the test site's total labor force (Virginia Division of State Planning and Community Affairs, 1971b).

Both light and heavy industry in the Norfolk test site are concentrated along the numerous navigable water bodies and rail lines in the northwest quarter of the region. In many instances these industries are related to the port activities. Even those industrial plants built after World War II have for the most part followed this pattern of development, and these new plants, with a few exceptions, have limited themselves almost entirely to locations within Norfolk or Portsmouth (Southeastern Virginia Planning District Commission, 1962).

Industrial development has long been lacking in Virginia Beach and Chesapeake (outside of South Norfolk) as a result of a lack of facilities, utilities and services required for industry.

Three large intensively developed industrial concentrations exist in the Norfolk test site: Norfolk, Portsmouth, and South Norfolk in Chesapeake. South Norfolk industries, located primarily along the waterfront, are involved in boat building and repair, the manufacture of agricultural chemicals, food processing, and steel fabrication. Portsmouth's basic industry is shipbuilding and repair, but the city's industries also manufacture chemicals, wood products, apparel and peanut butter. Norfolk's industry exists in two zones, an inner zone of concentrated industry and an outer ring of miscellaneous manufacturing. The major manufacturers (with employment of 50 or more) are listed in table 3-13. Although a variety of manufacturing does exist, food processing dominates the number of plants, with 8 out of a total of 33 manufacturers. Five plants manufacture metal products, and four plants manufacture apparel and textile products. The largest single manufacturing employers in Norfolk are an automobile assembly plant and a newspaper.

Only three major industries are listed for Virginia Beach in 1971 in the "Industrial Directory of Virginia," 1972, and only one of them, a steel fabricating plant, was in existence before 1950. The other two, a bakery and a manufacturer of ready mixed concrete, were established in 1966 and 1968, respectively.

Table 3-13--Major manufacturing establishments in the city of Norfolk

NAME	PROJECT	Approximate Employment a/ March, 1972
Air-A-Plane Corporation	Refrigeration and air conditioning units	50-99
Allegheny Pepsi-Cola Bottling Co., Inc.	Soft drinks	100-249
American Bank Stationary Co.	Blankbooks and looseleaf binders	50-99
American Cigar Co., Div. of American Brands, Inc.	Tobacco stemming	50-99
Anjay Fashion Mfg. Co., Inc.	Women's suits and coats	50-99
Atlantic Furniture Mfg. Co., Inc.	Wooden upholstered furniture	50-99
Baker Sheet Metal Corp.	Sheet metal works	50-99
Ballard Fish and Oyster Co.	Fresh and frozen seafood	100-249
Baltimore Bakery, Inc.	Bakery products	50-99
Bemis Company, Inc.	Textile bags	100-249
Berkeley Machine Works & Foundry Co.	Iron and nonferrous castings	100-249
Best Ever Ice Cream	Ice Cream and frozen deserts	50-99
Birtchered Dairy, Inc.	Milk and Ice Cream	100-249
Champale Products Corp.	Malt liquors	50-99
Colonna's Shipyard, Inc.	Shipbuilding and repairing	100-249
Dixie Jute Bagging Corp.	Textile bagging	100-249
F.S. Royster Guano Co.	Fertilizers	100-249
Ford Motor Co.	Motor vehicles	Over 1,000
General Foam Plastics Corp.	"Gena foam" plastics for insulation	500-999
Globe Iron Construction Co., Inc.	Fabricated structural steel	100-249
Guide Publishing Co., Inc.	Newspapers	50-99
Hall-Hodges Co., Inc.	Fabricated structural steel	50-99
J.H. Miles Co., Inc.	Fresh and frozen seafood	100-249
J.G. Gill Go., Inc.	Roasted coffee	50-99
Kotarides Baking Co., Inc.	Bakery products	100-249
Landmark Communications, Inc.	Newspapers	Over 1,000
M & B of Norfolk	Wire products	50-99
McGrath Coat Co.	Apparel	50-99
Virginia Tent and Awnings Co.	Tent-awnings	50-99
Weaver Fertilizer Co., Inc.	Nitrogenous fertilizers	50-99
J. G. Wilson Corp.	Metal doors, sash & trims	100-249

a/ Employment is given as a range in order not to reveal actual figures. The cut-off point for inclusion in the listing is 50.

From: Virginia Division of State Planning and Community Affairs, Data Summary Norfolk City, 1973, pp. 16-18.

Sources: Virginia Employment Commission; Virginia State Chamber of Commerce, Industrial Directory of Manufacturing in Virginia, (Richmond: Virginia State Chamber of Commerce, 1972); Commonwealth of Virginia, Division of Industrial Development, unpublished material.

The future expansion of industrial land in the Norfolk test site, as projected by the Southeast Virginia Regional Planning District Commission, is presented in table 3-1 . The greatest growth between 1975 and 1985 is expected to occur in Chesapeake and Virginia Beach with much less growth occurring in Norfolk and Portsmouth. Those manufacturers announcing plans to locate in the study area since 1970 include boat building and repair, meat processing and packaging, machinery assembly, prefinished panelling and molding and others (Virginia Division of State Planning and Community Affairs, 1971b). The decision to establish a Volvo assembly plant in Chesapeake is likely to have a large impact on that city.

Extractive Land Use
(Classification category 14, Level II)

With only 87 ha (214 acres) or .05 percent of the total, extractive land use is the second smallest in area of the Level II land use categories. CARETS interpreters detected extractive land only in Portsmouth and Virginia Beach with 18 ha (45 acres) and 68 ha (169 acres), respectively.

The detection of extractive sites, especially of the type existing in the Norfolk test site presents several problems. Sand or gravel operations often appear on high-altitude aircraft photography as areas under construction. Also, sand and gravel excavations may be too small to map or may fill with water and appear as artificial impoundments. Several abandoned pits, filled with water, occur along the Norfolk-Virginia Beach toll road. Because of the difficulty in identifying extractive operations, the revision of the USGS land use classification (Anderson and others, in press) classifies such extractive areas along with areas under construction and fill operations as barren land.

The Norfolk test site is located in the coastal plain province, which is underlain basically by unconsolidated sand and clay strata. Sand mixed with gravel also occurs in low ridges and along the rivers. Construction materials are thus readily available in many parts of the area. The location of extractive sites may depend upon the quality of the sand, clay, or gravel or the availability of undeveloped land that can be used for extraction.

The extraction and production of unprocessed and processed sand is significant in Virginia Beach where several companies run operations. In 1969 Virginia Beach ranked as the second Virginia county or city producer of sand and gravel (Virginia Division of State Planning and Community Affairs, 1973a). Since many of these operations are below minimum mapping size, the amount of extractive land use mapped may not reflect the true amount of land in such use.

Transportation, Communications, and Utilities
(Classification category 15, Level II)

Transportation and communication are vital to all urban areas. A transportation advantage often results in original settlement, provides access to and from a populated area, encourages commerce, and attracts industries to an urban area. Transportation thus sustains the life of a city, permits it to expand outward, and always has direct and indirect consequences on the land use surrounding its arteries, terminals, and route intersections. The Norfolk study area first developed as a port, and its role as a port and as the world's largest concentration of naval facilities is still primary. Yet also important are its railroad and highway links which perform transportation functions at which the port has not been successful.

The limitation of this report to a discussion of areas south of Hampton Roads is somewhat arbitrary. Newport News and Hampton, north of Hampton Roads, although separated from the Norfolk test site are really part of the same economic region, and now that they have been connected to Norfolk by a bridge-tunnel, are becoming even closer to Norfolk and Portsmouth. They share similar economic characteristics in an unusually high military concentration, a dependence on the port and bulk shipments, the limited role of manufacturing in their economies, the limitations inherent in relation to their regional hinterland, and in an unusual dispersal of centralized functions (Norfolk City Planning Commission, 1967).

The same water bodies that have served the Norfolk area so advantageously have also until very recently acted to divide the area and limit access from one city to the other. Not until the 1952 completion of the Downtown Tunnel were Norfolk and Portsmouth connected by road. In 1957, the Hampton Roads Bridge Tunnel connected Norfolk and Hampton for the first time. The Midtown Tunnel, completed in 1962, provided better access between Norfolk and Portsmouth. And in 1964, the Chesapeake Bay Bridge Tunnel was completed, connecting the Norfolk area with Virginia's Eastern Shore, as well as providing a shorter route between northern States and Florida. Transportation problems were not all cured, but the area was united by road.

Transportation and communication land use in the Norfolk study area in 1970 amounted to 3,049 ha (7,535 acres) or 1.7 percent of the total land area. Of this, 1,272 ha (3,142 acres) were in Norfolk, 972 ha (2,401 acres) in Virginia Beach, 538 ha (1,330 acres) in Chesapeake, and 268 ha (662 acres) in Portsmouth. The transportation and communications category basically includes highway interchanges, terminal facilities, railroad stations, parking lots, airports, seaports, docks, shipyards, and watercourse control structures. It is likely, however, that more transportation land use was not mapped than was mapped because of the existence of streets, roads, highways, parking lots, railroad rights of way, and other linear features or transportation facilities below minimum mapping size or inseparably mixed with other land uses.

The area measurement of parking lots in the central business districts of Norfolk and Portsmouth has revealed that parking lots comprise up to 14 percent of commercial areas of Norfolk and 6 percent of commercial areas of Portsmouth. In suburban shopping centers, the percentage of parking lots is much higher. Norfolk's Military Circle Shopping Center, the area's largest regional center, was found to have 49 percent of its area in parking lots in 1970.

Researchers found the percentage of areas classified as residential, but actually consisting of streets to vary greatly among sample sites. The NVPDC reported 7,322 ha (18,093 acres) of land in streets within the test site in 1965. In a Geography Program study, researchers found residential, grid-patterned streets to comprise 7 to 10 percent of the total for residential areas sampled, and one recently constructed suburban residential area in Chesapeake with curving streets, cul de sacs, and no sidewalks to have 16 percent of its area in streets.

Seven trunk line railroads and 53 major truck line carriers serve the Norfolk area. The railroads include the Chesapeake and Ohio, Norfolk and Western, Penn Central, Southern, Seaboard Coast Line, and the Franklin and Danville. All are linked by the Norfolk and Portsmouth Beltline Railroad (Virginia Division of State Planning and Community Affairs, 1973b).

Besides the Norfolk Municipal Airport, where a 1500-foot main runway extension and a new passenger terminal complex have recently been completed, the Norfolk study area has two smaller noncommercial airfields in Chesapeake: The Chesapeake-Portsmouth Airport and the South Norfolk Airport.

The highway system of the Norfolk study area is of great importance to the economic development of the region. Interstate Highway 64, connecting Richmond and Norfolk is the only interstate highway extending to the ocean between New York City and Charleston, South Carolina. Connected to Hampton by the Hampton Roads Tunnel, the Norfolk section of this highway is scheduled for completion in 1975. A second parallel tunnel is now under construction, and I-264, I-464, and I-564 will act as feeder highways to the north, west, and south. The other major highway in the study area is the Norfolk-Virginia Beach toll road, connecting I-64 in Norfolk with Virginia Beach. This road not only serves to transport vacationers to Virginia Beach's resort areas, but parallels the band of relatively recent suburban housing and population growth between the two cities.

Institutional Land Use
(Classification category 16, Level II)

The mapping of institutional land in the Norfolk test site, only included those areas containing structures or development uniquely associated with the functions of the institutions. A high school's track or football field would be classified as institutional, whereas a wooded area, a golf course, or an airfield on a military base would be classified as forest, urban open, and transportation, respectively, rather than as institutional. The 4,630 ha (11,441 acres) or 2.6 percent of the Norfolk test site that are classified as institutional do not, therefore, represent the total land area owned and controlled by institutions. A better idea of this total as well as an indication of the dominant influence of military bases (by far the largest component of institutional land use) is the total of 9,116 ha (22,509 acres) of military owned land, amounting to 5.2 percent of the total of the study area. This extensive amount of military land listed in table 3-14 contains many of the differing rural and urban land uses, and is extremely significant because it is relatively uninfluenced and uncontrolled by municipal or State government.

Table 3-14--Major military installations in the Norfolk test site

Jurisdiction	Total Area of Bases in Hectares	Percentage of Area	Installations
Chesapeake	2,754	3.1	Army Nike Site Fentress Naval Auxillary Air Station U.S. Naval Communications Station
Norfolk	1,097	8.0	Naval Operations Base
Portsmouth	810	11.0	Naval Hospital Naval Shipyard
Virginia Beach	4,455	6.6	Dam Neck Naval Weapons Training Facility Fort Story Little Creek Naval Amphibious Base Camp Pendleton (National Guard) Oceana Naval Air Station
Total Test Site	9,116	5.2	

Source: Southeastern Virginia Planning District Commission, 1969b.

Also military property occupies city land that is not taxable. For example, over 40 percent of Norfolk's net land area with improvements is not subject to the city's real estate taxes (Norfolk City Planning Commission, 1967, p. 25). On the other hand, parts of the developed or undeveloped military lands hold the potential for being declared surplus by the military and offered for sale to one of the cities. For example, the U.S. Army declared the Hampton Roads Army Terminal surplus, and the city of Norfolk acquired the base as the site for a major containerized general cargo facility (Norfolk City Planning Commission, 1967).

The 1970 institutional land use as delimited from high-altitude aircraft photography for the four constituent cities of the Norfolk test site is presented in table 3-15.

Table 3-15

INSTITUTIONAL LAND USE, 1970

	Norfolk	Portsmouth	Virginia Beach	Chesapeake
Hectares	1,104	295	2,150	1,081
Acres	2,729	728	5,313	2,671
% of total land within city	6.8	2.6	2.7	1.2

Virginia Beach has the most institutional land. Norfolk, however, has the highest percentage of institutional land use with 6.8 percent. These statistics might differ considerably for Portsmouth, if the Naval Shipyard there were classified as insitutional rather than industrial. As the largest military area in Portsmouth, the Naval Shipyard covers 344 ha (850 acres) or 4 percent of the city's total area. This base has 324 permanent buildings, 53 km of railroad tracks, 48 km of paved streets and 9.6 km of pier space (Breese and Hammer, 1968).

Many important institutions are too small to be mapped at a scale of 1:100,000, but among those large enough are schools, colleges and universities, and hospitals.

Strip and Cluster Land Use

(Classification category 17, Level II)

One task of the CARETS project has been testing the useability of the USGS Circular 671 land use classification, both for what can be detected successfully using remote sensor data and for the kind of data users desire. The strip and cluster category was designed to identify linear urban development along transportation arteries and for use in smaller cities and towns where the mixed nature of the land use makes separate land uses indistinguishable. Interpreters can detect such land use with relative ease, but reviewers have criticized this category for being a land use pattern rather than a use. The proposed revision of Circular 671 has eliminated the strip and cluster category.

This category comprised 1,671 ha (4,129 acres) or 0.9 percent of the total land area in the Norfolk test site. Interpreters found the most extensive strip and cluster development to occur in Chesapeake (1,329 ha, 3,284 acres) with lesser amounts in Virginia Beach (233 ha, 575 acres) and Portsmouth (109 ha, 270 acres). Interpreters found none of this pattern in Norfolk.

The strip and cluster pattern, as mapped by the CARETS project, is basically a rural phenomenon that consists primarily of residences mixed with some small commercial or institutional enterprises. As mentioned previously in the discussion of residential land use, much of the strip and cluster areas of Chesapeake could (and perhaps should) have been classified as residential.

Mixed Urban Land Use
(Classification category 18, Level II)

The urban mixed category is one designed for areas within large cities (a population greater than 50,000) where a single land use does not predominate or where several uses exist but are too small to be separated. In the Norfolk test site only 27 ha (66 acres) of such land have been mapped. Interpreters identified mixed urban land only in Virginia Beach, and this area is basically commercial mixed with other uses.

Open and Other Land Use
(Classification category 19, Level II)

The urban "open and other" land use category, 19, is a wide category including all land within an urban setting that is not developed with structures and does not fit into one of the nonurban categories such as water, forest, barren, wetlands, or agricultural. Open and other land may be well developed as in the case of cemeteries or formal gardens or intensively used as in the case of parks, ski areas, or golf courses. This category also has included those urban areas under construction, a temporary condition that is reflected in the great amount of land use change in which category 19 is involved. Because category 19 generally implies the amenity of urban open space, the proposed revision of USGS Circular 671 has removed areas under construction from category 19 and reclassified them as barren land.

Interpreters detected a total of 4,267 ha (10,543 acres) of open and other land in the Norfolk test site for 1970, amounting to 2.4 percent of the total area. Virginia Beach, with 2,152 ha (5,317 acres) had more than twice the amount of open land as its nearest competitor, Norfolk, with 1,011 ha (2,499 acres). One can partially explain this greater amount by the number of golf courses and outdoor recreational facilities associated with a popular Atlantic coast resort and with military bases built when plenty of open land was available. Chesapeake and Portsmouth were found to have 670 ha (1,655 acres) and 434 ha (1,072 acres), respectively. Of their total land areas, 6.2 percent of Norfolk 3.8 percent of Portsmouth, 2.7 percent of Virginia Beach, and 0.7 percent of Chesapeake have been classified as open and other.

Largely because of areas under construction included in this category, the involvement of open and other land in land use change has been high. With the Level I scheme, the use of "under construction" as part of an urban category is quite valuable for change detection, since most areas under construction will eventually be converted to one of the urban categories.

Agricultural Land Use
(Classification categories 21-24, Level II)

Although experiencing rapid urbanization, the Norfolk test site is extensively engaged in agriculture. Agricultural land use in 1970 occupied 27.4 percent of the total test site area with 49,463 ha (122,222 acres). Only a small part of this is located in Norfolk or Portsmouth; much of the land classified as cropland and pasture in Norfolk (182 ha, 449 acres) and Portsmouth (807 ha, 1993 acres) may not be engaged in agriculture, but may be abandoned farmland being held for speculative purposes. The U.S. Department of Agriculture does not keep statistics for these two cities. Although considerable agriculture-to-urban land use change did occur in peripheral areas within the present city boundaries of Norfolk and Portsmouth between 1959 and 1970 (see figures 3-1 and 3-2), interpreters did not detect change within the cities between 1970 and 1972.

This discussion of agricultural land use will therefore concern the cities of Chesapeake and Virginia Beach, which in 1970 had 26,752 ha (66,104 acres) and 21,723 ha (53,676 acres), respectively or 29.3 percent and 27.3 percent of their total land areas.

Agricultural land in Chesapeake and Virginia Beach is declining. Between 1959 and 1970 the Norfolk test site experienced a net decline in agricultural land of 65 km^2 (see table 3-5).

According to the U.S. Census of Agriculture for 1969, the land in farms in Chesapeake totalled 28,059 ha (69,333 acres), which is somewhat less than that accounted for on CARETS land use maps, and a decrease of 1,056 ha (2,609 acres) from that reported in 1959. In Chesapeake, the 1969 Census of Agriculture reported 378 farms averaging 74 ha (183 acres) and having an average value per farm of $107,016. The number of farms in Chesapeake has dropped rapidly each census reporting year (every 5 years) since 1935 when it reported 1,267 farms. Between 1964 and 1969, farm income decreased 22 percent; value of crops declined 25 percent; and the value of livestock sold decreased 9 percent. Most of the decreases in crop sales, however, resulted from a sharp decline in the growing of nursery and greenhouse products. Approximately 35 percent of Chesapeake's farms in 1969 were classified as part-time enterprises. Agriculture is still of considerable importance in the economy, however, since the annual value of farm products reported in 1969 was over $6 million (U.S. Bureau of the Census, 1972a).

Chesapeake leads Virginia in the sales of nursery and greenhouse products, and ranks sixth in value of vegetables sold. The CARETS land use data base for Chesapeake had too coarse a resolution to detect any of this nursery or greenhouse land, which would be included in category 22. CARETS interpreters detected 35 ha (87 acres) of category 22 land, which also includes orchards, for Virginia Beach. Chesapeake is also one of the leading corn and soybean producing areas.

The principal sources of cash farm income are nursery and greenhouse products, milk, soybeans, corn, vegetables, poultry, hogs, cattle, and wheat (Virginia Cooperative Crop Reporting Service, 1972).

The 1969 Census of Agriculture reported that land in farms in the city of Virginia Beach totalled 21,241 ha (52,486 acres) as compared to the CARETS sum of 21,723 ha (53,676 acres). This amounted to a 3,196-ha (7,897-acre) decrease in farm acreage from that reported in the Census of Agriculture for 1959. Nevertheless, the value of all farm products in 1969 averaged nearly $8 million. Meat animals brought in the most money with 26 percent of the cash farm income. Dairying created the second highest cash farm income. Virginia Beach ranks second in the State of Virginia in income from nursery and greenhouse products, which contributed 16 percent of Virginia Beach's total farm income in 1969.

The composition by percentage of all farms in 1969 in Chesapeake and Virginia Beach is shown in table 3-16. Virginia Beach has a greater percentage of cropland harvested, whereas Chesapeake has a greater percentage of woodland and woodland pasture. Table 3-17 presents the cultivated areas for all major crops in the two cities. In Chesapeake and Virginia Beach, soybean cultivation is the greatest in area, followed by corn and wheat in Chesapeake and wheat and corn in Virginia Beach. With the exception of wheat, hay, and small grains, the major crops of these cities are row crops, which generally result in greater soil erosion than cover crops.

Table 3-16-- Farmland uses by percentage in 1969 for Chesapeake and Virginia Beach

	Chesapeake	Virginia Beach
Cropland Harvested	55.9%	70.2%
Cropland Pasture	6.2	2.5
All Other Cropland	10.0	10.7
Woodland and Woodland Pasture	17.8	13.5
All Other Land	10.1	3.1

Source: U.S. Bureau of the Census, 1972a

Table 3-17--Areas of principal crops in Chesapeake and Virginia Beach

Chesapeake

Crop	1960		1970		1971		1972	
	Hectares	Acres	Hectares	Acres	Hectares	Acres	Hectares	Acres
Corn	7,800	19,300	5,300	13,000	5,700	14,200	5,500	13,500
Wheat	1,100	2,600	2,300	5,700	2,500	6,200	2,600	6,500
Peanuts	100	200	0	0	50	105	50	115
Soybeans	7,000	17,400	9,600	23,600	9,100	22,500	9,000	22,200

Virginia Beach

Crop	1960		1970		1971		1972	
	Hectares	Acres	Hectares	Acres	Hectares	Acres	Hectares	Acres
Corn	5,000	12,300	3,900	9,700	4,100	10,200	3,700	9,100
Wheat	1,800	4,500	4,300	10,600	4,800	11,800	4,700	11,500
Soybeans	6,400	15,800	9,800	24,100	8,900	22,000	8,800	21,800

Source: Virginia Cooperative Crop Reporting Service, 1972; figures reported in acres.

A relatively recent trend that has had a significant impact within the Norfolk test site has been mechanization. Not only has the practice resulted in an increase in farm and field size but also a decrease in the total number of farms and the abandoment of patches of farmland too small for the economical use of machinery. Mechanization has also given farmers the capability of growing two cash crops every year. Corn, for many years a major crop, has a late harvesting date, which interferes with attempts at double cropping. As a result, a large part of the area formerly in corn has been converted to a soybean/winter-wheat rotation (U.S. Bureau of Sport Fisheries and Wildlife, 1966). The data in table 3-17 reflect this trend. Since 1960, the area planted in corn has decreased, whereas that planted in wheat, especially in Virginia Beach, has rapidly increased.

Another practice affecting agriculture in the region is a large increase in the use of pesticides and fertilizers. In the past 10-year period, the use of pesticides and fertilizers in Chesapeake has doubled (Personal correspondence with E. Taylor, agricultural extention agent, Chesapeake).

Figures presented earlier have revealed the importance of livestock to agriculture in the Norfolk test site. In 1972, The Virginia Cooperative Crop Reporting Service reported 2,800 head of cattle (1,100 of which were milk cows 2 years or older) and 4,500 hogs for Chesapeake. The areas of agricultural land devoted to feeding operations, according to the CARETS 1970 land use maps, included only 13 ha (31 acres) in Chesapeake and none in Virginia Beach. Table 3-16 shows that the percentage of total land in farms devoted to pasture in 1969 was 6.2 percent for both Chesapeake and Virginia Beach.

Soil capability is a vital aspect of agriculture anywhere. Table 3-18 lists the areas of cropland as classified by soil capability and presents an insight into the quality of Chesapeake and Virginia Beach agricultural land. Chesapeake and Virginia Beach have nearly equal areas of cropland, yet the amount of high quality Class I soil in Chesapeake is only 121 ha (300 acres) as opposed to 6,443 ha (15,921 acres) in Virginia Beach. Wetness is the major problem of nearly all of Chesapeake's cropland and over 70 percent of that in Virginia Beach. The other limitations, susceptibility to erosion and soil droughtiness, are minor in comparison.

Forest Land Use
(Classification categories 41 & 42, Level II)

As the predominant land use in the Norfolk test site, forest land covers a large portion of Chesapeake and Virginia Beach. Most of the discussion of forests will focus on these two cities because forest statistics have not been kept for the more urbanized Norfolk and Portsmouth.

Available information concerning forest areas and ownership in Chesapeake and Virginia Beach is presented in table 3-19. According to "Virginia's Timber,1966"(Knight and McClure, 1967), a very small portion of the commercial forest land in these two cities is publicly owned. In Chesapeake, only 2.7 percent of the forest (1,539 ha - 3,800 acres)

Table 3-18--Chesapeake and Virginia Beach land capability classes and areas

Class	Chesapeake Hectares	Acres
1	122	300
2W	1,950	4,819
3W	18,242	45,077
4W	4,249	10,498
7W	704	1,740
2S	40	100
8S	349	863
Total	25,657	63,397

Class	Virginia Beach Hectares	Acres
1	6,443	15,921
2E	894	2,210
2W	5,092	12,581
3W	13,837	34,190
Total	26,266	64,902

Capability classes

Class 1: well drained, level or nearly level, productive, easy to work

Classes 2-4: capable under good management of producing adapted plants, cultivated crops, pasture plants, and forest trees

Classes 5-7: not suitable for cultivated annual or short lived crops; but can be used for orchards, pasture, forest trees, or wildlife

Class 8: practically no agricultural value

Unfavorable soil conditions resulting in limitations or hazards to agriculture

E: dominant problem--susceptibility to erosion

W: problem with poor drainage, high water table and/or subject to overflow

S: droughty soils, resulting from sandiness, shallowness, or slowly permiable subsoil

The seriousness or intensity of limitation determines the capability class.

Source: Virginia Conservation Needs Inventory Committee, 1970

Table 3-19--Forest area and ownership in Chesapeake and Virginia Beach

	Chesapeake		Virginia Beach	
	Hectares	Acres	Hectares	Acres
Total commercial forest, 1957*	56,983.5	140,700	26,122	64,500
Decrease in commercial forest, 1957-65	770	1,900	6,561	16,200
Total commercial forest, 1965**	56,214	138,800	19,561	48,300
Publicly owned	1,580	3,900	1,377	3,400
Forest industry owned	8,140.5	20,100	1,053	2,600
Farmer owned	14,215	35,100	8,059	19,900
Miscellaneous privately owned	32,238	79,600	9,072	22,400
Wooded farmland - 1969 Census of Agriculture	4,860	12,000	2,880	7,112
CARETS aircraft total forest, 1970	52,706	130,234	22,773	56,272
Heavy crown cover	50,223	124,099	21,895	54,102
Light crown cover	2,483	6,135	878	2,170

*Source: Knight and McClure, 1967.

**Source: U.S. Forest Service, Virginia District, 1965.

is publicly owned, existing on military installations. Approximately 41 ha (100 acres) of forest land is in parks or other areas unavailable for commercial use. Virginia Beach possesses 19,561 ha (48,298 acres) of commercial and 2,673 ha (6,600 acres) of productive reserved forests, including State-owned property, most notably Seashore and False Cape State Parks. The rest of the publicly owned land (2.9 percent of Virginia Beach's total forest) is held by military installations, the Back Bay Wildlife Refuge, and watershed development areas (Virginia Division of State Planning and Community Affairs, 1973a).

The privately owned forests are held by the forest industry, farmers, and "miscellaneous" owners, which might include investors, speculators and housing developers. These figures, though the most recently published and available, are somewhat out of date. The city of Portsmouth annexed some Chesapeake forests in 1968, and the Dismal Swamp forests have recently become public.

The 1969 Census of Agriculture lists considerably smaller sums of wooded farmland, 4,860 ha (12,000 acres) for Chesapeake and 2,800 ha (7,112 acres) for Virginia Beach.

CARETS Level II forest summaries are the most up-to-date. Although not revealing ownership, they are probably most reliable in that the forest category represents one of the more easily detectable land cover features on color infrared photography. Forest patches below the minimum recording size (200 m on the ground) and measurement inaccuracies explain most deviation from the actual amount of forest. A change detection study will allow for the updating of information without conducting a new survey.

LANDSAT can as well be a valuable tool in gathering information relating to forests. Researchers found a difference of only 5,960 ha (14,716 acres) when comparing forest acreage derived from LANDSAT with that obtained from high-altitude photography for October 1972.

The net decline in forest growth revealed in table 3-19 cannot be explained by the commercial harvesting of trees. Although foresting operations have decreased, the net forest loss has resulted from the clearing of land for other reasons, particularly conversion to agricultural use, highway construction, and urban development. CARETS change detection studies show that 45.7 percent of forests cut between 1959 and 1970 in the Norfolk test site have been converted to agricultural uses. Between 1970 and 1972, 46.6 percent of forest lands cut were converted to pasture and croplands, although 30 percent were converted to the urban category "open and other," including areas under construction.

Forest types in the Norfolk test site are shown in figure 1-4 and areas of forest types in Chesapeake and Virginia Beach are presented in table 3-20. Two basic forest types are characteristic of the Virginia tidewater: (1) the loblolly pine-hardwoods and (2) the bottomland hardwoods. The loblolly pine-hardwood forest developed as a response to

Table 3-20--Areas of principal forest types in Chesapeake and Virginia Beach, 1966

Chesapeake

Forest Type	Hectares	Acres
Loblolly Pine	8,757	21,637
Oak-Pine	11,336	28,010
Oak-Hickory	12,116	29,939
Oak-Gum Cypress	23,944	59,166

Virginia Beach

Forest Type	Hectares	Acres
Pond Pine	1,049	2,591
Oak-Hickory	17,954	44,364
Oak-Gum-Cypress	1,220	544

Source: Knight and McClure, 1967

shifting agriculture and the abandonment of fields, the frequency of forest fires, and the clear cutting of forests. Being shade intolerant, pines do not grow well in the shade of other trees but thrive on abandoned fields or forest areas cleared by cutting or fire. With the loblolly pines well established, tolerant hardwoods, capable of growing in the shade of the pines, become mixed with the pines and unless stopped by cutting or fire will eventually dominate the forest. The more established agriculture of the present and the better control and prevention of fires has resulted in less natural growth of loblolly pines and more of the associated hardwoods (Gottmann, 1968).

The bottomland hardwoods, which thrive under moist lowland conditions, comprise the forests of the Dismal Swamp. Trees in these forests include a mixture of hardwoods (black gum, tupelo and red maple) and some softwoods (white cedar and cypress). Originally some 1,554 km^2 (600 mi^2) in extent, the Dismal Swamp has been reduced to a less than 777-km^2 (300-mi^2) area in southern Virginia and northern North Carolina. Much of the lost swamp has been drained and its soils converted into farmland. Proposals have been made to drain the entire swamp for conversion to agricultural use.

As early as the 18th century, the value of the Dismal Swamp forests has been appreciated. In 1760, the first canals were dug to help transport harvested wood. White cedar, abundant in the swamp, was prized for its use for gunpowder, charcoal, saw timber, and shingles (Gottmann, 1968). The inaccessability of much of the area has helped to protect the forests, and although frequently susceptible to fires, the boggy ground has prevented the spread of fire. The two corporations that owned much of the swamp during the recent past engaged in lumbering operations only on a limited scale, cutting only trees of marketable size, leaving the others standing (Gottmann, 1968).

In January 1973, the Union Camp Corporation, through the Nature Conservancy, donated 19,840 ha (less than a fourth) of the Dismal Swamp, including Lake Drummond, to the United States Department of the Interior Bureau of Sport Fisheries and Wildlife, which has established a national wildlife refuge on the property. The same year the Bureau of Sport Fisheries and Wildlife designated the 85,000 ha or remaining viable wetland as the Great Dismal Swamp Study Area in which research is being conducted to determine the desirability and feasibility of protecting and preserving the ecological, scenic, recreational, historical and other resource values of the swamp.

Of the Great Dismal Swamp Study Area, the portion lying in Chesapeake is approximately 28,200 ha or 33.0 percent of the total swamp. This area consists of 27,000 ha of forest, 35.5 percent of the total forest area in the Norfolk test site. The Great Dismal Swamp study area also includes most of Lake Drummond. The Chesapeake portion of the study area comprises approximately 15.6 percent of the nonestuarine area of the Norfolk test site.

The creation of a natural wildlife refuge in the Dismal Swamp will contribute to the preservation of the bottomland bog forest. Yet as farms have claimed a large part of former swamp, many view residential expansion near the swamp as a great threat to its continued existence. If trends continue as they have in the recent past, less forest will be clear cut for commercial purposes in Chesapeake and Virginia Beach, but urban expansion will result in a decrease in the forest resources of the area.

Water
(Classification categories 51-55, Level II)

Water and water supply are important to any area, particularly for the Norfolk test site because of the area's role as a port and water-based resort area and the ecological importance of the water bodies that nearly surround and deeply penetrate the area. Water is one of the more easily detected land uses on color infrared film because water absorbs infrared rays. On the film, water normally appears as a dark shade of blue. USGS Circular 671 (Anderson and others, 1972) lists five Level II categories of water: 51, streams and waterways; 52, natural lakes; 53, reservoirs or artificial impoundments; 54, bays and estuaries; and 55, other water.

All five categories are represented in the Norfolk test site, but the predominant water type is the bay and estuary. Including only that estuarine water within census tracts, the area of bays and estuaries amounts to 18,262 ha (45,084 acres) or 9.2 percent of the area of the Norfolk test site. Table 3-3 reveals that Virginia Beach has the most estuarine water, followed by Portsmouth, Norfolk, and Chesapeake.

CARETS interpreters detected 1,050 ha of streams and waterways in Virginia Beach and 179 ha in Chesapeake consisting primarily of freshwater streams and canals. A minimum mapping size of 2 mm was established, prohibiting the mapping of some important streams narrower than the minimum of 200 m on the ground. Also included in this category is the Albemarle and Chesapeake Canal, part of the link in the Intracoastal Waterway connecting the Chesapeake Bay and Albemarle Sound.

The area of natural lakes in the Norfolk test site is larger than that of reservoirs but only because of Lake Drummond in the Dismal Swamp, which occupies an area of 1,175 ha (2,901 acres) in Chesapeake. The water of Lake Drummond, stained dark by tannic acid from decaying vegetation, is totally free of bacteria. Its depth fluctuates, but it is fairly shallow, with approximately 90 percent of its area 3 m deep or less, and much of its area 1 m deep or less. No streams flow into Lake Drummond. Rather, it receives its water from precipitation, surface runoff, or seepage through the peat layers of the swamp. It is drained by a 5.6-km long ditch feeding into the Dismal Swamp Canal, which reportedly uses 11,256,200 liters (3 million gallons) of water from the lake whenever the canal locks are manipulated to allow for the passage of vessels. During drought periods, the drainage of Lake Drummond has been severe, and the Dismal Swamp Canal, used primarily for recreation rather than commerce, has been forced to close temporarily. The problem of Lake Drummond and the Dismal Swamp Canal is one that the Great Dismal Swamp National Wildlife Refuge is attempting to face through extensive studies of the area.

Interpreters detected water in reservoirs or artificial impoundments in all four constituent cities but predominantly in Virginia Beach, which was found to have 352 ha (871 acres). The reservoir category represents a use that has been steadily increasing. According to CARETS change detection studies, 152 ha (376 acres) of agricultural land, forest, urban open and other land, and nonforested wetlands changed to reservoirs between 1970 and 1972. Many of these reservoirs have been built as a part of city water supplies for use in recharging ground water supplies and for storage of surface runoff and water received from outside the area.

The final water category to be discussed is category 55, "other." This category was found only in Portsmouth and consists of the 786 ha (1,943 acres) of water impounded within the levees of the Craney Island disposal area. This water has been steadily decreasing and will eventually disappear as the area is filled in.

Nonforested Wetlands
(Classification categories 61 & 62, Level II)

The discussion of nonforested wetlands in the Norfolk test site will be brief due to the previous discussion of the Craney Island fill project and the environment impact study of the Back Bay area to be presented in chapter 4.

A total of 7,878 ha (19,466 acres) of nonforested wetlands were measured from the CARETS 1970 land use maps, comprising 4.4 percent of the Norfolk test site. Existing in all four cities, these wetlands predominatly occur in Virginia Beach with 6,124 ha (15,132 acres). Chesapeake was found to have 1,163 ha (2,874 acres), Portsmouth, 424 ha (1,047 acres), and Norfolk, 167 ha (413 acres).

These wetlands, many of which are tidal marshes, occur on the fringes and in the islands of the bays and estuaries, on the flood plains of streams, and in other poorly drained interior lands.

As in most urbanized areas, the nonforested wetlands in the Norfolk area are declining in size. Between 1970 and 1972, 76 ha (188 acres) of wetlands were converted to reservoirs in Virginia Beach and Chesapeake. CARETS change detection maps reveal that between 1959 and 1970,200 ha (494 acres) had changed from nonforested wetlands to urban uses, and 100 ha (247 acres) were drained for agricultural use. Along with flood plains, some marsh areas have been used for the dumping of industrial wastes. Also between 1959 and 1970, 500 ha of nonforested wetlands changed into forested areas, which could have resulted from the draining of areas or the lowering of the water table.

The nonforested wetlands of the Norfolk test site are predominantly vegetated. Portsmouth's Craney Island artificial fill area is the large exception, and Chesapeake is the only other city where interpreters detected nonvegetated wetlands for 1970. These nonvegetated wetlands consisted of two separate mud flats along Southern Branch of the Elizabeth River. The nonvegetated wetlands pose an interpretation problem caused by cyclical or periodical innundation by stream flow or tidal action.

Barren Land
(Classification categories 72-75, Level II)

With .8 percent of the total area, barren land forms only a small portion of the land use of the Norfolk test site. Detected only in Virginia Beach, barren land totalled 1,434 ha or 3,543 acres, of which 1,374 ha consisted of beach, 34 ha of sand other than beach, and 27 ha of "other" barren land.

The location of much of this barren land is along the coastal fringes of Virginia Beach from west of the Chesapeake Bay Bridge Tunnel to Cape Henry and the barrier beach south of the most intensely urbanized area of Virginia Beach. Narrower beaches in Virginia Beach and Norfolk have widths below the minimum mapping size and were thus not mapped. Sand other than beaches consists basically of small isolated patches of unvegetated dunes and sand ridges west of beaches. These are located in the same area as some of Virginia Beach's sand excavations.

A discussion of the barrier beaches comprising most of the barren land in the Norfolk test site and the consequences of man's attempts to stabilize them will be presented in the section of this report concerning coastal and wetland environmental problems.

LAND USE CHANGE, 1970-72

The CARETS project conducted two 1970-72 change detection studies for the Norfolk test site, the different methodologies of which are explained in chapter 2. The results of the more thorough and reliable change detection study are shown in tables 3-21 and 3-22 which include change that could be identified only to Level I using LANDSAT and that identified to Level II.

The transitory nature of many areas classified as urban "open and other," (19) resulted in a great amount of change in this category between 1970 and 1972. Table 3-21 shows that, of the 3,916 ha of land that changed, 616 ha or 15.7 percent of the total changed from an open land use and that 1,216 ha or 31 percent changed to an open land use. Of the areas changing to the "open and other" category, 60 percent changed from cropland and pasture and 35 percent changed from heavy crown cover forest.

Agricultural land was also highly involved in change between 1970 and 1972. Though showing a gain of 204 ha (504 acres) of agricultural land converted from forest, table 3-22 reveals a total decrease of 1,376 ha (3,401 acres) of farmland. Of this change, 1,256 ha changed to urban uses, 84 ha reverted to forest, and 36 ha became residential land. In two years, the Norfolk test site experienced a net loss of 1,172 ha of agricultural land.

An examination of tables 3-21 and 3-22 reveals that many of the change trends of the 1959 to 1970 period are continuing. Urban land continues to expand at the expense of the open space that surrounds it.

Table 3-21--Land use change 1970-72 for the Norfolk test site derived from LANDSAT imagery and high-altitude photography: Levels I & II*

From: Land use category	To: Land use category	Hectares	Acres	% of Total change
Residential (11)	Open and other (19)	104	257	2.7
Institutional (16)	Residential (11)	16	40	0.4
Open and other (19)	Residential (11)	432	1,067	11.0
Open and other (19)	Commercial (12)	108	267	2.8
Open and other (19)	Institutional (16)	20	49	0.5
Open and other (19)	Strip and cluster (17)	8	20	0.2
Open and other (19)	Light crown cover forest (42)	8	20	0.2
Open and other (19)	Reservoirs (53)	40	99	1.0
Agriculture (2)	Urban (1)	396	979	10.1
Agriculture (2)	Extractive (14)	8	20	0.2
Agriculture (2)	Forest (4)	84	208	2.1
Cropland and pasture (21)	Residential (11)	84	208	2.1
Cropland and pasture (21)	Commercial (12)	16	40	0.4
Cropland and pasture (21)	Strip and cluster(17)	24	59	0.6
Cropland and pasture (21)	Open and other (19)	728	1,799	18.6
Cropland and pasture (21)	Reservoirs (53)	36	89	0.9
Forest (4)	Urban (1)	96	237	2.5
Forest (4)	Extractive (14)	8	20	0.2
Forest (4)	Agriculture (2)	104	257	2.7
Heavy crown cover forest (41)	Residential (11)	84	208	2.1
Heavy crown cover forest (41)	Commercial (12)	108	267	2.8
Heavy crown cover forest (41)	Open and other (19)	240	593	6.1
Heavy crown cover forest (41)	Cropland and pasture (21)	100	247	2.6
Heavy crown cover forest (41)	Light crown cover forest (42)	304	751	7.8
Light crown cover forest (42)	Open and other (19)	56	138	1.4

*Detailed breakdown of item j, table 2-11.

Table 3-21--(continued)

From: Land use category	To: Land use category	Hectares	Acres	% of Total change
Water (5)	Urban (1)	8	20	0.2
Bays and Estuaries (54)	Open and other (19)	64	158	1.6
Water other (55)	Unvegetated wetlands (62)	532	1,315	13.6
Vegetated wetlands (61)	Open and other (19)	24	59	0.6
Vegetated wetlands (61)	Reservoirs (53)	76	188	1.9
TOTAL CHANGE		3,916	9,676	99.9

Table 3-22--Land use change 1970-1972 for the Norfolk test site: Level I only *

From Land Use Category	To Land Use Category	Hectares	Acres	% of total Level I change
Urban (1)	Forest (4)	8	20	0.3
Urban (1)	Water (5)	40	99	1.4
Agriculture (2)	Urban (1)	1,256	3,104	43.0
Agriculture (2)	Forest (4)	84	208	2.9
Agriculture (2)	Water (5)	36	89	1.2
Forest (4)	Urban (1)	592	1,463	20.3
Forest (4)	Agriculture (2)	204	504	7.0
Water (5)	Urban (1)	72	178	2.5
Water (5)	Wetlands (6)	532	1,315	18.2
Wetlands (6)	Urban (1)	24	59	0.8
Wetlands (6)	Water (5)	76	188	2.6
TOTAL		2,924	7,225	100.2

*Derived from data presented in table 3-21

CHAPTER 4

ENVIRONMENTAL IMPACT APPLICATIONS

Effective land use planning is the key to environmental protection and enhancement. Land use planning requires an understanding of the way environmental and socioeconomic processes work to produce distinctive patterns of land and water use. The CARETS project has produced a substantial data base of land use, land use change, geologic, and hydrologic information for investigating the interrelationships among these processes. This chapter stresses the relationships between land use and environmental changes in parts of the Norfolk test site. For example, the demands of urban centers for recreational land and the need for waste disposal are considered in concert with changes in land use and environmental quality observed in the coastal zone. Chapter 4 concerns three broad environmental/land use planning applications of CARETS data: (1) air quality impact of land use, (2) surface geologic and hydrologic factors affecting land use, and (3) coastal and wetland environmental problems associated with land use.

AIR QUALITY IMPACT OF LAND USE PATTERNS AND CHANGE TRENDS[1/]

[1/] Reed, Wallace E. and John E. Lewis, Land Use Information and Air Quality Planning, v. 7 of CARETS final report.

With the implementation of the Clean Air Act of 1970 and several subsequent Supreme Court decisions spelling out the intent of the act, air quality planners need to evaluate more effectively the impact of land use goals on present and future air quality. Furthermore, these planners must be able to respond with plans that accommodate existing activities and pressures for regional growth within the framework of deadlines for achieving national air quality standards. Although most air quality control regions are not equipped with instruments and personnel to handle effectively the air quality problem, land use data, predictions of emission characteristics, local meteorological information, and techniques for measuring and estimating pollutant concentrations are potentially available to them. These data and estimating techniques provide local air quality planners the basis for reevaluating earlier strategies and implementing plans for reducing excessive levels of pollution. They also provide the opportunity to examine alternative control strategies involving such nondegradation concepts as: prohibiting emission increases in any area; permitting nonsignificant deterioration to occur up to fixed limits throughout a region; determining on a case-by-case basis the significant deterioration that will result from a land use change; and establishing a zoning program permitting various densities of emission in different areas of a region.

The interrelationships among land use strategies and air quality are evaluated by identifying present and future land use pattern relationships, identifying the air pollutants, as associated with land use types, and determining the impact of specific pollutant concentrations on various land uses. Air quality levels can be reduced or maintained by employing a number of strategies depending on the relationship of these variables within a region. Table 4-1 is a listing of strategies that can be used individually or in combination.

Norfolk Example: Land Use and Sulfur Dioxide Concentrations

The Norfolk area was selected as a test site for evaluating the air quality impact of land use patterns and the role of timely land use data in assisting in the development of alternative air pollution control strategies. This area is situated on the coastal plain of Virginia at the entrance to the Chesapeake Bay and contains the only stretch of ocean frontage easily accessible to much of central Virginia and northern North Carolina. Local air flows and pollutant dispersion are most influenced by a nearly flat topographic profile; extensive water surface in wetlands, rivers, and estuarine embayments; proximity to the open Atlantic Ocean; and an extensive mixture of agricultural and forest lands. Sulfur dioxide is a major pollutant in this area resulting from the types of fuel oil used for heating and power generation, the high sulfur inputs and other area manufacturing processes, the patterns of shipping and other traffic flow, and the age of many area plants and processing technologies.

The Virginia State Air Pollution Control Board, charged with implementing air quality controls, had little time and money for collecting a wide range of land use and physical information on the Norfolk area. In preparing its initial inventory of sulfur dioxide emissions, the board

Table 4-1--Land use strategies for air quality planning

I. Source Modifications

A. Emission Controls

1. Change in type of activity and processes

2. Change in fuel and other process inputs

3. Installation of emission control devices

B. Emission Timing

1. Change in timing of emissions

C. Emission Location

1. Change in the spatial distribution of stationary and mobile sources with respect to air flow and receptor patterns

II. Air Flow Modifications

A. Air Flow Modifications

1. Changes in surface roughness

2. Changes in surface albedo

3. Changes in transpiring surface pattern

4. Changes in local precipitation

5. Changes in thermal diffusivity

III. Receptor Modifications

A. Receptor Acitivities

1. Change in the activities and processes impacted

B. Receptor Contact

1. Change in air contact through structural and air conditioning modifications.

used available land use information to determine the location of large point sources and to identify a grid system of areas with relatively homogeneous densities and types of activities that could be used as the basis for estimating area source emissions. Point source emissions for annual and seasonal periods were reported by various firms and institutions or were estimated from the timing, scale, and type of activity of the source. The board found that the region, as a whole, did not exceed primary standards, which are the most stringent of EPA requirements. To reduce concentrations in specific locations, however, an area-wide emissions reduction strategy and air quality sampling program were adopted, focused primarily on controlling local point sources. Instituted in July 1972, this program requires that all sources emitting specific quantities and types of pollutants provide detailed information concerning types, levels and timing of activities, as well as physical conditions such as stack height, pollutant exit velocities, and temperatures that affect emission levels and diffusion.

Once the Board had developed a basic control strategy and an implementation plan for sulfur dioxide levels in the Norfolk area, it assigned to its Region VI, in Virginia Beach, the task of expanding, detailing, and implementing either this or some alternative strategy that it might develop. Land use, emission, and meteorological data were used to evaluate effectively the adopted and alternative strategies. The Norfolk area's physical, land use, and air flow characteristics provided an excellent context for evaluating the usefulness in air quality planning of an experimental national land use information system being developed by the United States Geological Survey, Geography Program (GP). GP supplied Region VI staff with CARETS 1:100,000-scale Level II land use maps compiled from high-altitude aircraft photography.

Researchers overlaid the CARETS 1970 Level II land use map with an area-source emissions estimating grid previously constructed by the Air Pollution Control Board. This grid consists of varying sized cells of homogeneous land uses and land use densities. Researchers then calculated the area and percentage of different Level II land uses for each grid cell. Using the CARETS photomosaic and Southeastern Virginia Planning District Commission records, they broke down residential areas into Level III categories of low, medium, and high density housing and plotted the Level III residential locations by grid cell on the Level II map.

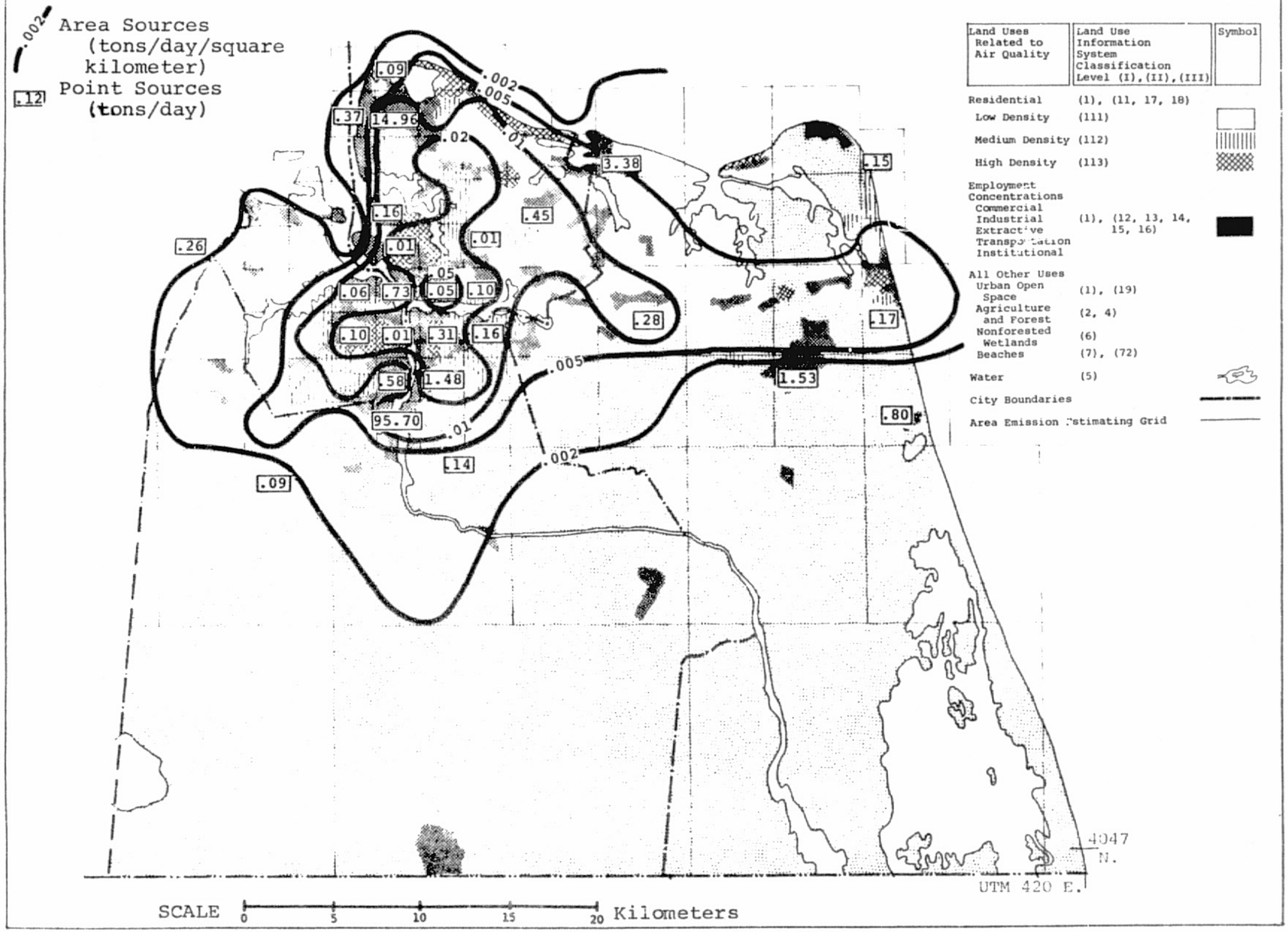
On the basis of the updated land use analysis and change in traffic patterns, researchers developed an estimated average annual winter 1972 area source emissions inventory. They placed area source information into a diffusion model, producing maps (figure 4-1) depicting estimated annual sulfur dioxide emissions in the Norfolk-Portsmouth SMSA for 1972. The isolines on this map connect values for the centroids of the grid cells. Figure 4-1 reveals the concentration of such land uses as industrial, commercial, transportation, institutional, and high density residential, which emit large quantities of sulfur dioxide. These uses are surrounded by lower density residential areas, water, and nonurban uses. Emission levels in tons per day along with stack heights, exit temperatures, and

Figure 4-1

NORFOLK - PORTSMOUTH SMSA

ESTIMATED ANNUAL EMISSIONS OF SULFUR DIOXIDE, 1972

SELECTED 1970 LAND USE



other characteristics needed for diffusion estimating procedures were determined from 1972 emission registration forms or from the board's 1971 inventory.

High annual emissions from point and area sources reflect high concentrations of industrial, commercial, and residential activities in central Norfolk and Portsmouth (figure 4-1). To the east, lower emissions reflect the mix of low density housing, water, agricultural, sporadic commerical, transportation, and industrial land use. Figure 4-2, the 1985 annual emission pattern, reflects estimated impacts of currently adopted control programs, rules governing existing point and area sources, and anticipated patterns of residential growth. In figure 4-2 this pattern has been plotted over the current land use base, indicating the expected urban expansion into nonurbanized areas.

Norfolk Example: Sulfur Dioxide Control Strategies

The emission and physical characteristics of the Norfolk area and the political realities facing area planners in 1972 made a source emissions control strategy seem to be the easiest to implement. This strategy required limited land use and meteorological information to identify sources and predict general diffusion patterns. It was also clearly in line with the goal of reducing total nationwide emissions regardless of spatial pattern.

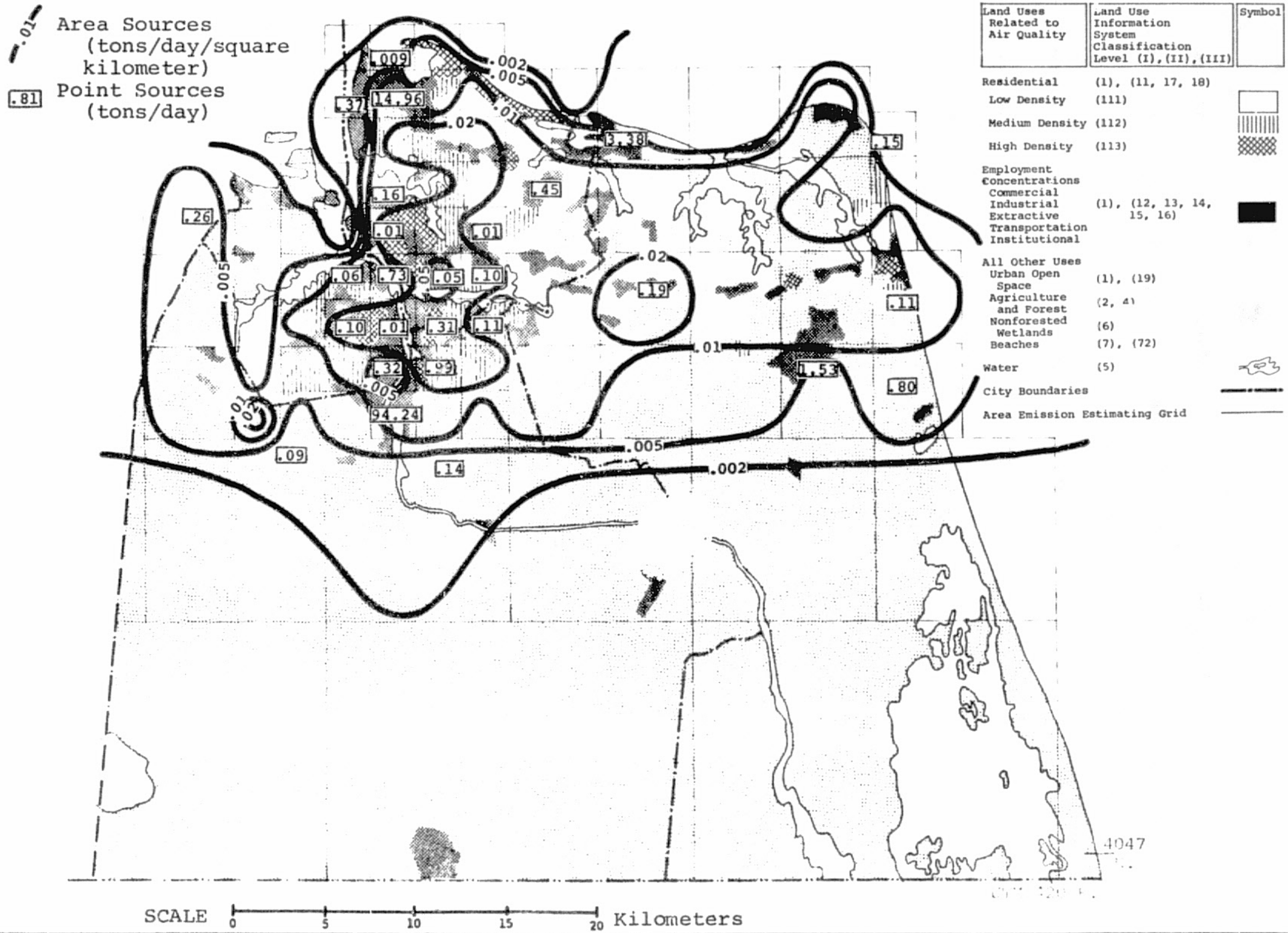
With the Federal Government undertaking control of mobile emission sources, State and regional action has been directed toward controlling the emissions of point and area sources. Such control is being accomplished through establishing rules permitting emission levels directly related to levels of materials processed or fuels burned

Figure 4-2

NORFOLK - PORTSMOUTH SMSA

ESTIMATED FUTURE EMISSIONS OF SULFUR DIOXIDE, 1985

SELECTED 1970 LAND USE



by various activities. Each activity is expected to achieve these emission levels through installing pollution control equipment. By 1972 three alternate land use strategies were proposed:

(1) to reorganize the spatial pattern of emission sources and receptors;

(2) to develop land uses modifying regional and local air flows; and

(3) to change the timing of various activities in the area.

In view of legislatively established time limits, these strategies appeared to be either feasible or too costly.

The board's initial analysis and sampling indicate that sulfur dioxide concentrations are below national standards throughout most of the region. By controlling the emissions of selected point sources, the initial strategy could easily accommodate regional goals for growth and land use as long as one could assume that emissions of new or changed land uses would be allowed to deteriorate surrounding air quality no more than the limits set by national secondary standards.

The 1973 court decisions and changes in EPA regulations have forced a reevaluation of this initial strategy. This reevaluation is focused on dealing with a range of environmental goals, including growth and economic stability. Such goals may result in land use patterns significantly deteriorating the quality of air around all but the largest emitters in the region. These major sources must, of course, reduce their emissions to meet primary and secondary standards as soon as possible and install the best available control equipment at some future date.

Spatial patterns and levels of activities may be most affected by the adoption of one or more of the nonsignificant deterioration-oriented strategies suggested by EPA in July 1973: region-wide emissions freeze; limited emissions increase; case-by-case analysis; or emission density zoning. To accomplish these strategies requires a clear definition of significant deterioration in any part of the region. With such a definition, priorities must be established indicating which activities in any area will be required or permitted to reduce or expand their emissions.

Study results reveal that the projected expansion of area sources throughout the region will result in measurable deterioration in sulfur dioxide levels. If the existing sampling program verifies that significant deterioration is occurring in the vicinity of recently built area sources, then encouraging patterns of area source growth in the southern and western portions of the regions would be expected to redt total regional concentrations associated with area sources. Such a land use strategy for air quality control should be balanced against the costs and problems it may create for achieving other environmental goals.

The problems involved in evaluating the effectiveness and equity of alternative land use strategies to achieve or maintain air quality goals for the Norfolk area demonstrate the need for improved land use, air quality, and meteorological data along with extensive estimating of pollutant concentrations under varying assumptions of land use patterns and definitions of significant deterioration. In addition, the political viability of land use strategies to achieve air quality goals versus strategies to achieve other environmental goals must be assessed.

Of most immediate significance for the objectives of the CARETS investigation, the Norfolk air quality impact study demonstrated the utility of the land use/environmental impact model for air quality applications. Furthermore, Level II land use data at 1:100,000-mapping scale, when augmented by the Level III residential categories of "low density, medium density, and high density" proved adequate for the estimation of air quality levels.

GEOLOGICAL AND HYDROLOGICAL FACTORS AFFECTING LAND USE PATTERNS AND CHANGE TRENDS[1/]

[1/] Derived from "Description and Physical Properties of Earth Materials in the Portsmouth-Norfolk Area," compiled by Sherman K. Neuschel, USGS, 1972.

In urban areas undergoing rapid change and facing the pressures of intense land use competition, a knowledge of landforms, earth materials, and hydrology is a necessity for sound land use planning. Aware of the need, the CARETS project is having maps of surficial geology produced, which are keyed to the 1:100,000 photomosaics and land use maps. They may be manually overlaid on the CARETS land use, census tract, or hydrology maps and eventually digitized and overlaid automatically on other data sets.

Surficial geology has a particularly strong site influence on agriculture, engineering works, and all the "urban and built-up" land uses. This section is designed to illuminate relationships between land use and surficial geology in the Norfolk test site, examine land use problems resulting from surface geologic and related hydrologic factors, and discuss the suitability of the land into which urban areas might expand.

The Earth Materials Map of the Portsmouth-Norfolk Area, Southeast Virginia (figure 4-3), reflects the underlying geological terrain of a coastal plain having characteristic low altitude and relief, with north-scuth trending ridges. The low relief, high water table, and coastal location produce extensive areas of wetlands and attendant problems of drainage and flooding. The ridges and escarpments forming the areas of greater relief contain much of the area's construction materials, sand and gravel, vital for urban construction.

The Earth Materials Map, though derived from existing geological and soil survey data, does not present the information in the conventional formats of those data sources. Rather, the map units are intended to be quickly and easily interpretable by planners and others who require a regional-scale perspective on the suitability of various parts of the area for specific land uses. The following discussion elaborates on the 14 "earth materials" units into which the Norfolk test site has been divided.

Figure

EARTH MATERIALS MAP OF THE PORTSMOUTH-NORFOLK AREA, SOUTHEAST VIRGINIA

Compiled by
Sherman K. Neuschel
1972

Earth material unit 1, "sand and gravel, sand" is concentrated primarily in the test site's northern urban areas, along the Diamond Springs Escarpment and Oceana Ridge and along the fringes of the eastern, southern, and western branches of the Elizabeth River. This category includes the best overall land in the test site for most uses. Soils developed in this unit are well-drained, friable, sandy loams, which form the most productive agricultural lands in the test site. The water table is generally 0.61 - 1.4 m below the surface. These soils also have the best adaptability to irrigation and to earth works in wet periods and are the most suitable as a source of topsoil. With the exception of areas in southern Virginia Beach that are intensively farmed, this land is predominantly in urban uses. Its good drainage makes it the most suitable earth material in the area for foundations. The cities of Norfolk and Portsmouth were first established on this land and many of the industrial, commercial, and transportation facilities associated with the harbor are located here.

Unit 1 is also the test site's most suitable source of construction materials. Though sand is somewhat more widespread, the gravel found in former beach ridges is the only source of gravel within the area. Importing a bulk material like gravel can substantially increase its cost and thus the cost of any construction project needing it.

Earth material unit 2, "silty sand," consists of former barrier beaches, near-shore deposits, and higher areas adjacent to the present drainage. These lands are moderately well drained, with a seasonably

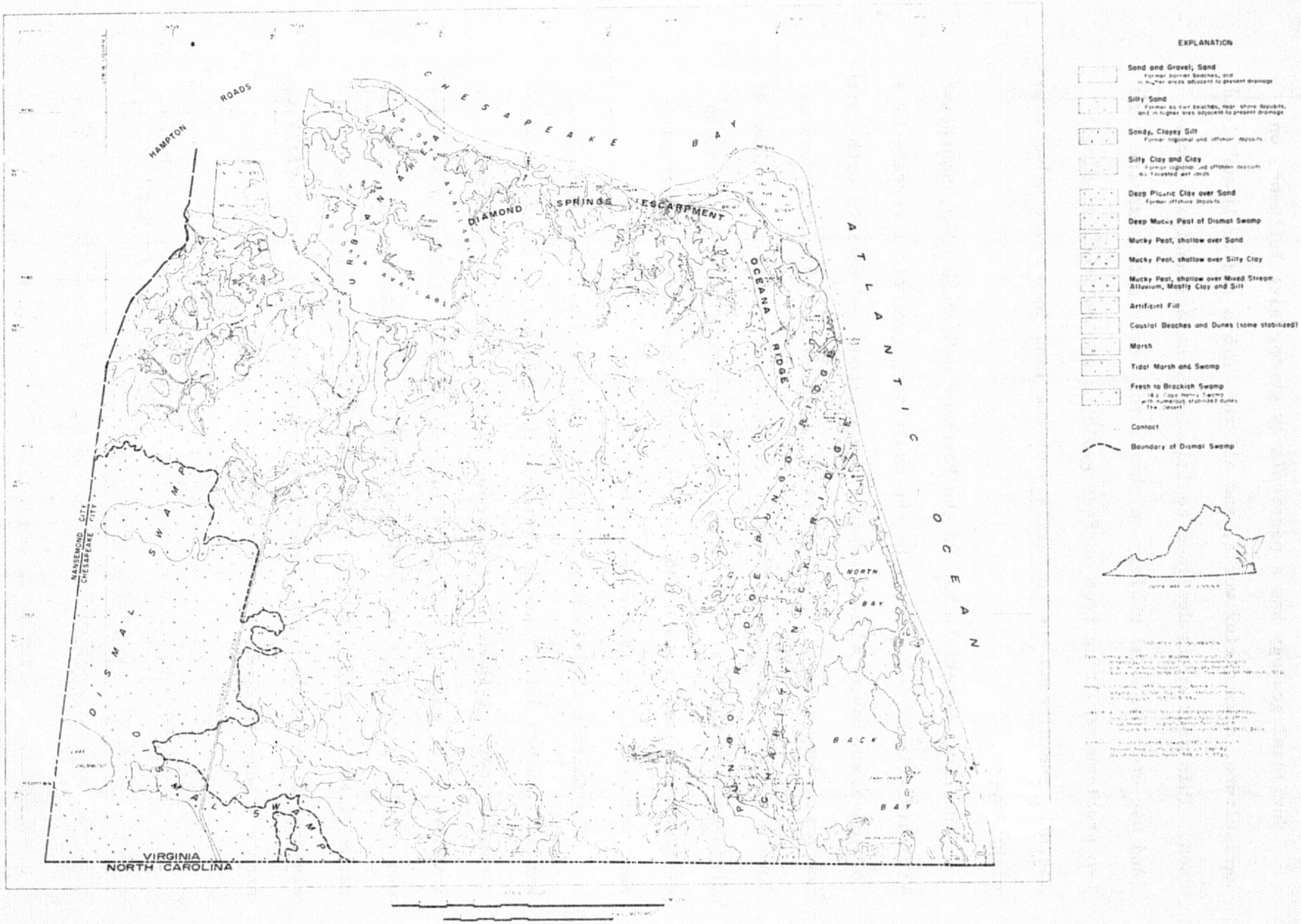


Figure 4-3

EARTH MATERIALS MAP OF THE PORTSMOUTH-NORFOLK AREA, SOUTHEAST VIRGINIA

Compiled by
Sherman K. Neuschel
1972

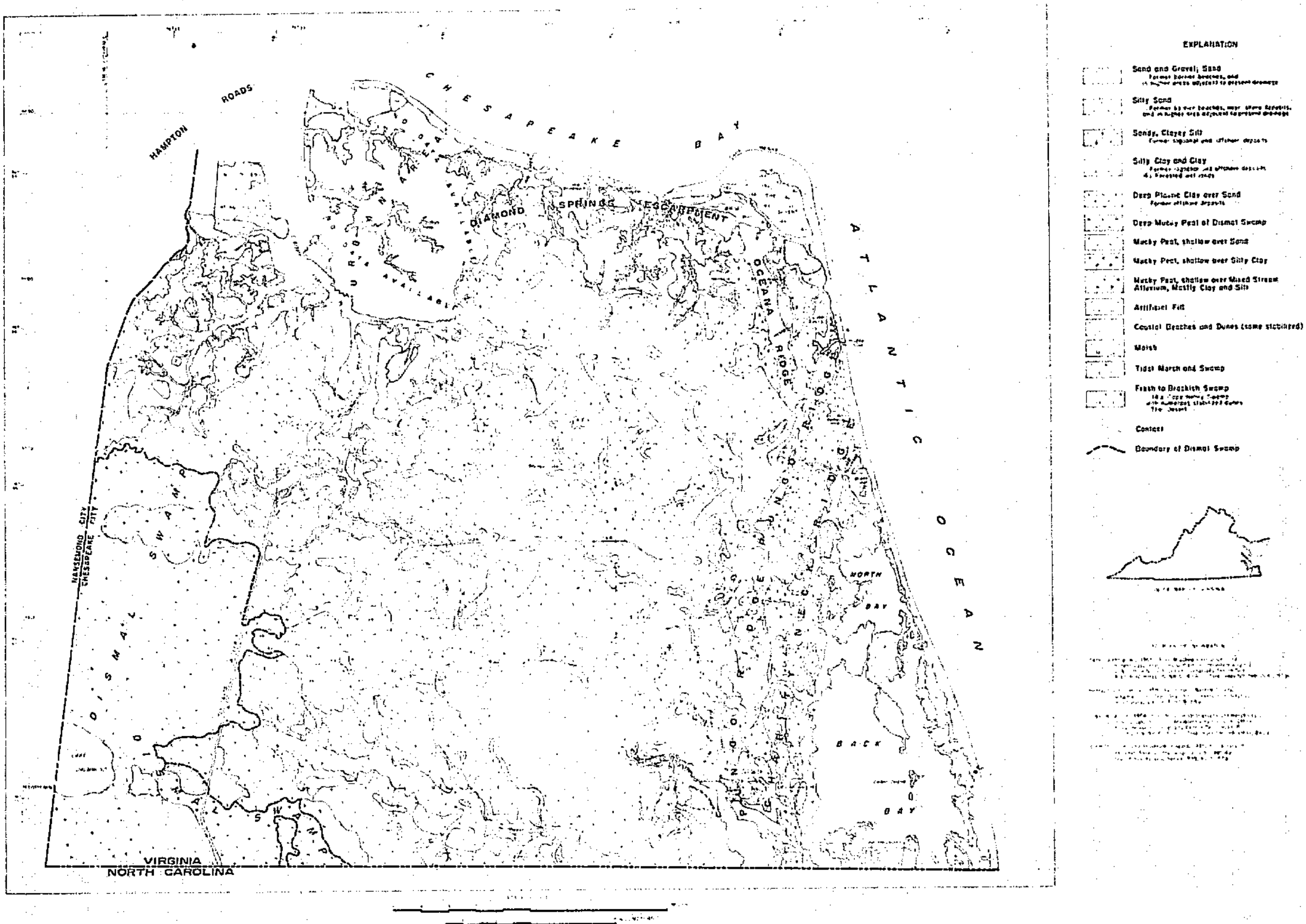


Figure 4-3

EARTH MATERIALS MAP OF THE PORTSMOUTH - NORFOLK AREA, SOUTHEAST VIRGINIA
Compiled by
Sherman K. Neuschel
1972

of land use change via remote sensing techniques aids in developing relationships between short-term uses of man's environment and the maintenance of long-term environmental quality.

Land Use Policy and Planning Assistance Act

The Land Use Policy and Planning Assistance Act presently before Congress proposes to provide Federal technical assistance through grant-in-aids to the States to assist them in developing and improving their capacity for land use planning and management. The major purpose of the Act is to assist the States in development of planning processes. The Act requires the States to develop land use programs that concentrate on five categories of critical areas. These five categories are: (1) areas of critical environmental concern (e.g. beaches, floodplains, significant wildlife habitats, historic areas); (2) key facilities (e.g. major airports, highway interchanges, recreational facilities, and facilities for the development, generation, and transmission of energy); (3) large scale development (e.g. industrial parks or major subdivisions); (4) public facilities or utilities of regional benefit (e.g. solid waste disposal or sewage systems); and (5) land sales or development projects (e.g. major recreational or second homesite developments in rural areas). All in all, the act's fundamental purpose is to encourage land use decision making at the State and local levels as well as bolster land use planning and management of areas that are of more than local concern--wetlands, coastal zones, floodplains, power plant siting, open space, and strip mining. Remote sensing provides an important tool in developing land use planning and management capabilities.

Urban Transportation Planning Program, 1969

The U. S. Department of Transportation's Urban Transportation Planning Program has sought to promote the development of transportation systems embracing various modes of transport. To accomplish this objective the States are authorized to develop long-range highway plans and programs that are formulated with due consideration to their probable effect on the future development of urban areas. Land use studies are important elements in the transportation planning process. The U.S. Department of Transportation (1969) defines the type of land use study required if States are to comply with Federal funding requirements:

1) The land use study should incorporate a wide variety of undertakings, all of which are aimed at providing an accounting of the current land use activity structure of the study area and the most probable or desirable future structure.
2) The land use study should include the following items for the entire study area:
    a) an inventory of the location and intensity of existing land use activities, including vacant land;
    b) an analysis of past trends to aid in determining land consumption rates and the most likely location patterns of households and business firms; and
    c) the distribution of an area-wide forecast of population and economic activity to small areas.
3) The land use data needed as a base for developing the forecast may be obtained from field surveys, local planning agencies,

other secondary sources, or a combination of these (remote sensing provides an additional data source.)

CONCLUSION

The perspective that came from close involvement with the user institutions, particularly the Southeastern Virginia Planning District Commission, greatly enhanced the value of the study to the Federal agency sponsors and research team. On the one hand, a close-up view of the local and regional planning process illustrated the complexity of that process and the considerable size and variety of its required data inputs, of which land use is only one. Planning budgets are small, and budgets for remote sensing and land use data are even smaller.

On the other hand, awareness of data needs deriving from a variety of Federal and State programs is fostering improved cooperation and coordination among the many agencies whose policies and jurisdictions impact on the Norfolk-Portsmouth area. This investigation, involving a topic (land use) that cuts across the interests of so many governmental and administrative bodies, provides an example of such cooperation.

One can conclude from this study that land use and land cover data derived from remote sensing sources have important roles to play in regional planning and in a number of environmental study applications. The establishing in the future of a regional land use and environmental monitoring system such as that demonstrated by the CARETS project, by an operational agency, would seem to have significant value to the agencies having land and resource planning and management concerns. Such a system would have even more value if it could provide the increased detail indicated by the user agency responses, and if data could be delivered quickly and in formats that are truly compatible with the user agency requirements.

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Appendix A

LAND USE CATEGORIES IN THE CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE DATA BASE

Level I Categories and Map Notation Used	Level II Categories and Map Notation Used
1 - URBAN & BUILT UP	11-Residential 12-Commercial and services 13-Industrial 14-Extractive 15-Transportation, communications, and utilities 16-Institutional 17-Strip and clustered settlement 18-Mixed 19-Open and other
2 - AGRICULTURAL	21-Cropland and pasture 22-Orchards, groves, bush fruits, vineyards, and horticultural areas 23-Feeding operations 24-Other
4 - FOREST LAND	41-Heavy crown cover (over 40%) 42-Light crown cover (10% to 40%)
5 - WATER	51-Streams and waterways 52-Lakes 53-Reservoirs 54-Bays and estuaries 55-Other
6 - NONFORESTED WETLANDS	61-Vegetated 62-Bare
7 - BARREN LAND	72-Sand other than beaches 74-Beaches 75-Other

Appendix B

U.S. GEOLOGICAL SURVEY
LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

LEVEL I		LEVEL II	
1	Urban or Built-up Land	11	Residential
		12	Commercial and Services
		13	Industrial
		14	Transportation, Communications and Utilities
		15	Industrial and Commercial Complexes
		16	Mixed Urban or Built-up Land
		17	Other Urban or Built-up Land
2	Agricultural Land	21	Cropland and Pasture
		22	Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
		23	Confined Feeding Operations
		24	Other Agricultural Land
3	Rangeland	31	Herbaceous Rangeland
		32	Shrub and Brush Rangeland
		33	Mixed Rangeland
4	Forest Land	41	Deciduous Forest Land
		42	Evergreen Forest Land
		43	Mixed Forest Land
5	Water	51	Streams and Canals
		52	Lakes
		53	Reservoirs
		54	Bays and Estuaries
6	Wetland	61	Forested Wetland
		62	Nonforested Wetland
7	Barren Land	71	Dry Salt Flats
		72	Beaches
		73	Sandy Areas Other than Beaches
		74	Bare Exposed Rock
		75	Strip Mines, Quarries, and Gravel Pits
		76	Transitional Areas
		77	Mixed Barren Land
8	Tundra	81	Shrub and Brush Tundra
		82	Herbaceous Tundra
		83	Bare Ground Tundra
		84	Wet Tundra
		85	Mixed Tundra
9	Perennial Snow or Ice	91	Perennial Snowfields
		92	Glaciers

Appendix C

PROPOSED LEVEL III CATEGORIES FOR USE WITH THE USGS LAND USE CLASSIFICATION SYSTEM IN THE CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE
(Preliminary for Review and Testing)

James R. Anderson, Ivan L. Hardin, William B. Mitchell
Office of the Chief Geographer
U.S. Geological Survey

This is a preliminary example of how a land use categorization at Level III can be made for use with Levels I and II of "A Land Use Classification System for Use with Remote Sensor Data" (USGS Circular 671). The Level III categories have been designed to make maximum use of remcte sensing data but may not be identifiable solely by the use of remote sensor data.

Number Code	Categories
1	Urban and Built-up Land

11 Residential

- 111 Single-family household units
- 112 Multi-family household units
- 113 Group quarters
- 114 Residential hotels
- 115 Mobile home parks or courts
- 116 Transient lodgings
- 119 Other

12 Commercial and Services

- 121 Wholesale trade areas
- 122 Retail trade areas
- 123 Business, professional, personal services
- 124 Cultural, entertainment, and recreational activities
- 125 Other

13 Industrial

- 131 Mechanical processing
- 132 Heat processing
- 13 Chemical processing
- 134 Fabrication and assembly
- 135 Food processing
- 136 Other

14 Extractive

- 141 Stone Quarries
- 142 Sand and gravel pits
- 143 Open pit or strip mining
- 144 Oil, gas, sulphur, salt, and other wells
- 145 Shaft mining
- 149 Other

15 Transportation, Communications and Utilities

151 Highways, auto parking, bus terminals, motor freight
152 Railroads and associated facilities
153 Airports and associated facilities
154 Marine craft facilities
155 Telecommunications, radio and television facilities
156 Electric, gas, water, sewage disposal, solid waste
159 Other

16 Institutional

161 Educational facilities
162 Medical and health facilities
163 Religious facilities
164 Military areas (built-up areas only)
165 Correctional facilities
166 Governmental administration and services
169 Other

17 Strip and Clustered Settlement

(No further breakdown recommended at Level III)

18 Mixed

(No further breakdown recommended at Level III)

19 Open and Other

191 Improved (such as golf courses, cemeteries, parks, etc.)
192 Unimproved
199 Other

2 Agricultural Land

21 Cropland and Pasture

211 Cropland from which new crops, close-sown or hay crops have been or will be harvested
212 Cropland lying idle, having crop failure or being used for soil improvement crops or conservation purposes
214 Pasture
219 Other

22 Orchards, Groves, Bush Fruits, Vineyards and Horticultural Areas

221 Fruit and nut trees
222 Bush fruits
223 Vineyards
224 Nurseries and floricultural areas
229 Other

23 Feeding Operations

231 Cattle feed lots (including holding lots for dairy animals
232 Poultry and egg houses
233 Hog feed lots
239 Other

3 Rangeland

31 Grass

(No further breakdown at Level III required for the CARETS area.)

32 Savannas (Palmetto prairies)

(No further breakdown at Level III required for the CARETS area.)

34 Desert Shrub

(No further breakdown required at Level III for the CARETS area.)

4 Forestland

41 Deciduous

411 Afforesting areas
412 Light crown cover 10-39%
413 Heavy crown cover 40% or greater
419 Other

42 Evergreen

421 Afforesting areas
422 Light crown cover 10-39%
423 Heavy crown cover 40% or greater
429 Other

43 Mixed

431 Afforesting areas
432 Light crown cover 10-39%
433 Heavy crown cover 40% or greater
439 Other

5 Water

51 Streams and waterways

(No further breakdown at Level II required for the CARETS area.)

52 Lakes

(No further breakdown at Level III required for the CARETS area.)

53 Reservoirs

(No further breakdown at Level III required for the CARETS area.)

54 Bays and Estuaries

541 Bays
542 Estuaries

59 Other

6 Nonforested Wetlands

61 Vegetated

611 Brackish marsh
612 Fresh water marsh
619 Other

62 Bare

621 Brackish bare areas
629 Other

7 Barren Land

71 Salt Flats

(No further breakdown at Level III required for CARETS area.)

72 Beaches

721 Sandy Beaches
722 Gravelly, rocky beaches
723 Mud shorelines

73 Sand other than beaches

(No further breakdown at Level III required for CARETS area.)

74 Bare exposed rock

(No further breakdown at Level III required for CARETS area.)

75 Disturbed Land

8 Tundra (No further breakdown recommended at this time.)

9 Permanent Snow and Icefields (No further breakdown recommended at this time

Appendix D

Level III Land Use Demonstration Categories for Identifying the Manmade Causes of Ground Water Pollution

Level II[a]	Level III[b]
11 Residential	
	111 Low density (0.5-2 dwelling units/acre)
	112 Medium density (3-4 dwelling units/acre)
	113 High density (5-6 dwelling units/acre)
	114 Very high density (7+ dwelling units/acre)
12 Commercial, Services, and Institutional	
	121 Structures
	122 Landscaped areas
	123 Parking areas
	124 Solid waste disposal areas
	125 Other
13 Industrial	
	131 Heat processing industries
	132 Chemical processing industries
	133 Fossil fuel electrical power generation stations
	134 Nuclear electrical power generation stations
	135 Other
14 Transportation, Communications, and Utilities	
	141 Highways, vehicle parking facilities
	142 Railroads and associated facilities
	143 Airports and associated facilities
	144 Gas, petroleum, coal slurry, and other pipeline rights-of-way
	145 Sewage disposal facilities
	146 Solid waste sites (sanitary land fills)
	147 Other
15 Mixed (Including Strip and Clustered Settlements)	
	151 Industrial parks
	152 Other
16 Open and Other	
	161 Improved
	162 Unimproved
	163 Other
21 Cropland and Pasture	
	211 Cropland
	212 Pasture
	213 Other (including idle cropland)

Level II[a]	Level III[b]
22 Orchards, Groves, Bush Fruits, Vineyards, and Ornamental Horticultural areas	
	221 Orchards/groves
	222 Vineyards
	223 Other
23 Other (Including Confined Feeding Operations)	
	231 Cattle and swine feed lots
	232 Poultry and egg houses
	233 Other
31 Grasses and Forbes	
32 Shrubs and Scrub	
33 Palmetto Prairies	
34 Tundra	
35 Undifferentiated	
41 Deciduous Forestland	
42 Mixed Forestland	
43 Coniferous Forestland	
44 Undifferentiated Forestland	
51 Forested Wetland	
52 Nonforested Wetland	
61 Streams and Waterways	
62 Lakes	
	621 Surface mine associated lakes
	622 Other
63 Reservoirs	
64 Permanent Snow and Ice Fields	
65 Other	
	651 Industrial waste ponds
	652 Sewage lagoons
	653 Other

Appendix D (cont'd)

Level II[a]	Level III[b]
71 Salt Flats	
72 Beaches	
73 Sandy Areas Other than Beaches	
74 Bare Exposed Rock	
75 Strip Mines, Quarries, and Gravel Pits	751 Rock quarries
	752 Sand and gravel pits
	753 Open pit strip mining
	754 Oil, gas, sulfur, salt, and other well fields
	755 Shaft mines
	756 Areas under construction
	757 Other

[a]Classification scheme presented in Anderson and others [in press].

[b]Developed by Lennis G. Berlin and William B. Mitchell, USGS.

Appendix E

1970 LAND USE BY CENSUS TRACTS

NORFOLK TEST SITE

Canada Geographic Information System, 1973

Case Study for the U.S. Geological Survey

See Appendix A for key to categories

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION			P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
NORFOLK	1			11	1	236,18	88,3
	1			61	1	31,19	11,7
* AREA OF ABOVE SUBDIVISION		1	IS	267,44			
NORFOLK	2			11	1	489,78	95,8
	2			12	1	7,88	1,5
	2			16	1	12,93	2,5
	2			54	4	0,47	0,1
* AREA OF ABOVE SUBDIVISION		2	IS	511,00			
NORFOLK	3			11	4	261,84	54,1
	3			12	1	86,21	17,8
	3			16	1	15,42	3,2
	3			19	2	120,02	24,8
	3			54	2	0,27	0,1
* AREA OF ABOVE SUBDIVISION		3	IS	483,83			
NORFOLK	4			11	1	249,54	86,4
	4			19	1	0,81	0,3
	4			54	11	38,52	13,3
AREA OF ABOVE SUBDIVISION		4	IS	288,86			
NORFOLK	5			11	1	264,83	97,8
	5			19	1	5,93	2,2
AREA OF ABOVE SUBDIVISION		5	IS	270,76			
NORFOLK	6			11	1	307,70	94,9
	6			16	5	15,49	4,8
	6			19	5	1,21	0,4
* AREA OF ABOVE SUBDIVISION		6	IS	324,41			

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
NORFOLK	7	11	1	262.94	87.0
	7	16	1	24.79	8.2
	7	53	1	6.67	2.2
	7	61	1	7.75	2.6
* AREA OF ABOVE SUBDIVISION 7 IS 302.14					
NORFOLK	8	11	1	226.7.	79.9
	8	16	2	9.97	3.5
	8	53	2	47.02	16.6
* AREA OF ABOVE SUBDIVISION 8 IS 283.73					
NORFOLK	9	10	1	558.65	8.7
	9	11	9	570.76	8.9
	9	12	4	719.30	11.2
	9	13	1	62.32	1.0
	9	15	7	1321.59	20.6
	9	16	6	980.83	15.3
	9	19	8	892.68	13.9
	9	42	1	42.91	0.7
	9	53	1	39.88	0.6
	9	54	23	1217.15	19.0
* AREA OF ABOVE SUBDIVISION 9 IS 6406.00					
NORFOLK	11	11	1	135.08	74.7
	11	19	2	45.74	25.3
* AREA OF ABOVE SUBDIVISION 11 IS 180.83					
NORFOLK	12	11	2	411.48	46.3

LAND MANAGEMENT INFORMATION SYSTEMS ENVIRONMENT CANADA DATA SOURCE: U.S. GEOLOGICAL SURVEY

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	12	12	3	81.95	9.2
	12	54	1	394.93	44.5
* AREA OF ABOVE SUBDIVISION	12	IS 888.36			
NORFOLK	13	11	1	153.70	91.7
	13	12	1	11.93	7.1
	13	15	2	0.74	0.4
	13	19	2	1.26	0.8
* AREA OF ABOVE SUBDIVISION	13	IS 167.65			
NORFOLK	14	11	2	73.26	50.3
	14	12	2	72.31	49.7
* AREA OF ABOVE SUBDIVISION	14	IS 145.57			
NORFOLK	15	11	1	190.37	92.5
	15	12	1	8.69	4.2
	15	54	2	6.81	3.3
* AREA OF ABOVE SUBDIVISION	15	IS 205.87			
NORFOLK	16	11	1	156.00	100.0
* AREA OF ABOVE SUBDIVISION	16	IS 156.00			
NORFOLK	17	11	2	217.62	64.4
	17	12	3	46.78	13.8
	17	16	1	23.59	7.0
	17	54	1	50.01	14.8
* AREA OF ABOVE SUBDIVISION	17	IS 338.06			
NORFOLK	18	11	1	159.47	75.0
	18	12	2	29.86	14.0

PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	18	54	2	23.25	10.9
* AREA OF ABOVE SUBDIVISION 18 IS 212.52					
NORFOLK	19	11	1	183.12	84.1
	19	12	2	7.01	3.2
	19	16	1	19.28	8.9
	19	54	3	8.36	3.8
* AREA OF ABOVE SUBDIVISION 19 IS 217.76					
NORFOLK	20	11	1	157.87	60.2
	20	12	1	38.89	14.8
	20	54	4	64.98	24.8
	20	61	1	0.47	0.2
* AREA OF ABOVE SUBDIVISION 20 IS 262.21					
NORFOLK	21	11	2	248.56	55.1
	21	19	1	78.00	17.3
	21	54	1	124.78	27.6
* AREA OF ABOVE SUBDIVISION 21 IS 451.34					
NORFOLK	22	11	1	215.50	50.4
	22	12	1	36.60	8.6
	22	54	1	175.40	41.0
* AREA OF ABOVE SUBDIVISION 22 IS 427.50					
NORFOLK	23	11	1	195.41	52.4
	23	12	2	28.58	7.7
	23	16	1	33.77	9.1
	23	54	3	114.92	30.8
* AREA OF ABOVE SUBDIVISION 23 IS 372.75					

LAND MANAGEMENT INFORMATION SYSTEMS ENVIRONMENT CANADA DATA SOURCE: U.S. GEOLOGICAL SURVEY

PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
NORFOLK	24	11	2	320,66	28,7
	24	12	1	31,01	2,8
	24	54	1	766,35	68,5
* AREA OF ABOVE SUBDIVISION	24	IS 1118,02			
NORFOLK	25	11	1	216,09	50,5
	25	12	1	46,59	10,9
	25	13	1	7,62	1,8
	25	15	2	6,81	1,6
	25	16	2	73,89	17,3
	25	54	1	76,92	18,0
* AREA OF ABOVE SUBDIVISION	25	IS 427,92			
NORFOLK	26	11	1	21,78	9,2
	26	11	1	1,75	0,7
	26	12	1	134,16	56,8
	26	16	3	52,18	22,1
	26	54	1	26,22	11,1
* AREA OF ABOVE SUBDIVISION	26	IS 236,10			
NORFOLK	27	11	1	145,37	64,9
	27	12	1	78,62	35,1
* AREA OF ABOVE SUBDIVISION	27	IS 224,06			
NORFOLK	28	11	1	263,54	60,4
	28	12	3	60,95	14,0
	28	19	1	10,05	2,3
	28	54	1	102,15	23,4
* AREA OF ABOVE SUBDIVISION	28	IS 436,60			

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
NORFOLK	29	11	1	219.08	46.6
	29	12	1	95.35	20.3
	29	16	1	36.14	7.7
	29	19	1	90.22	19.2
	29	54	1	29.60	6.3
* AREA OF ABOVE SUBDIVISION 29 IS 470.39					
NORFOLK	30	11	2	247.19	78.3
	30	54	1	68.37	21.7
* AREA OF ABOVE SUBDIVISION 30 IS 315.56					
NORFOLK	32	11	1	194.07	98.0
	32	54	3	4.05	2.0
* AREA OF ABOVE SUBDIVISION 32 IS 198.12					
NORFOLK	33	11	2	234.82	73.9
	33	12	8	64.88	20.4
	33	16	1	0.47	0.1
	33	54	2	17.53	5.5
* AREA OF ABOVE SUBDIVISION 33 IS 317.70					
NORFOLK	34	11	6	184.04	60.4
	34	12	2	44.85	14.7
	34	16	1	43.97	14.4
	34	54	1	31.83	10.4
* AREA OF ABOVE SUBDIVISION 34 IS 304.63					
NORFOLK	35 01	11	2	59.21	43.1
	35 01	12	2	76.03	56.9
* AREA OF ABOVE SUBDIVISION 35 01 IS 137.25					

LAND MANAGEMENT INFORMATION SYSTEMS ENVIRONMENT CANADA DATA SOURCE: U.S. GEOLOGICAL SURVEY

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
NORFOLK	35 02	11	1	27.04	17.9
	35 02	12	2	78.03	51.7
	35 02	16	1	45.73	30.3
* AREA OF ABOVE SUBDIVISION 35 02 IS 150.80					
NORFOLK	36	11	1	60.22	32.2
	36	12	1	126.92	67.8
* AREA OF ABOVE SUBDIVISION 36 IS 187.14					
NORFOLK	37 +31	11	2	288.58	70.7
	37 +31	12	2	83.62	20.5
	37 +31	19	1	27.10	6.6
	37 +31	54	1	8.90	2.2
* AREA OF ABOVE SUBDIVISION 37 +31 IS 408.20					
NORFOLK	38	11	1	179.44	71.7
	38	12	1	7.35	2.9
	38	15	3	34.39	13.7
	38	19	1	29.13	11.6
* AREA OF ABOVE SUBDIVISION 38 IS 250.38					
NORFOLK	39	11	3	38.64	2.5
	39	12	1	14.50	0.9
	39	13	2	183.14	11.7
	39	15	3	542.02	34.8
	39	16	1	0.40	0.0
	39	54	2	780.61	50.1
* AREA OF ABOVE SUBDIVISION 39 IS 1559.32					

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION			P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
NORFOLK	40 01			11	1	76.35	66.5
	40 01			12	1	38.44	33.5
* AREA OF ABOVE SUBDIVISION	40 01	IS		114.79			
NORFOLK	40 02			11	1	118.63	71.7
	40 02			12	2	27.18	16.4
	40 02			13	1	8.97	5.4
	40 02			15	1	0.47	0.3
	40 02			54	3	10.52	6.2
* AREA OF ABOVE SUBDIVISION	40 02	IS		165.51			
NORFOLK	41			11	1	60.84	63.1
	41			12	3	13.56	14.1
	41			16	2	21.92	22.7
* AREA OF ABOVE SUBDIVISION	41	IS		96.30			
NORFOLK	42			11	1	84.59	51.4
	42			12	2	80.00	48.6
* AREA OF ABOVE SUBDIVISION	42	IS		164.52			
NORFOLK	43			11	3	115.34	51.9
	43			12	1	48.50	21.8
	43			13	1	36.08	16.2
	43			16	1	22.39	10.1
* AREA OF ABOVE SUBDIVISION	43	IS		222.31			
NORFOLK	44			11	2	175.10	75.4
	44			12	1	56.66	24.4
	44			16	1	0.54	0.2
* AREA OF ABOVE SUBDIVISION	44	IS		232.30			

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
NORFOLK	45	11	1	172.69	67.4
	45	12	1	29.75	11.6
	45	16	1	9.98	3.9
	45	41	1	43.85	17.1
* AREA OF ABOVE SUBDIVISION 45 IS 256.47					
NORFOLK	46	11	1	263.38	69.7
	46	15	2	3.85	1.0
	46	16	2	3.31	0.9
	46	19	1	0.54	0.1
	46	54	1	106.80	28.3
* AREA OF ABOVE SUBDIVISION 46 IS 377.87					
NORFOLK	47	11	4	143.96	36.2
	47	12	1	23.61	5.9
	47	15	1	110.50	27.8
	47	16	1	77.78	19.6
	47	54	1	41.90	10.5
* AREA OF ABOVE SUBDIVISION 47 IS 397.81					
NORFOLK	48	11	1	104.43	54.4
	48	12	2	15.38	8.0
	48	15	2	25.64	13.4
	48	54	1	46.48	24.2
* AREA OF ABOVE SUBDIVISION 48 IS 191.86					
NORFOLK	49	11	4	26.98	5.2
	49	12	2	321.15	61.6

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	49	16	1	65.64	12.6
	49	54	1	107.46	20.6
* AREA OF ABOVE SUBDIVISION 49. IS 521.50					
NORFOLK	50	11	1	84.27	13.0
	50	12	1	59.04	9.1
	50	13	1	99.13	15.3
	50	15	3	151.40	23.4
	50	19	1	30.63	4.7
	50	54	1	221.57	34.3
* AREA OF ABOVE SUBDIVISION 50 IS 646.11					
NORFOLK	51	11	3	261.19	50.0
	51	13	1	70.17	13.4
	51	19	1	36.64	7.0
	51	54	1	154.44	29.6
* AREA OF ABOVE SUBDIVISION 51 IS 522.44					
NORFOLK	52	11	2	270.26	83.0
	52	12	1	1.28	0.4
	52	13	1	4.05	1.2
	52	16	3	35.97	11.0
	52	19	1	8.70	2.7
	52	54	2	5.53	1.7
* AREA OF ABOVE SUBDIVISION 52 IS 325.79					
NORFOLK	53	11	2	113.50	43.5
	53	12	1	102.10	39.2

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	53	13	1	39.55	15.2
	53	15	2	2.90	1.1
	53	16	1	1.69	0.7
	53	54	1	0.68	0.3
* AREA OF ABOVE SUBDIVISION 53 IS 260.74					
NORFOLK	55	16	2	3.91	0.7
	55	11	1	258.80	43.6
	55	12	3	59.97	10.1
	55	15	1	34.77	5.9
	55	19	1	168.58	28.4
	55	53	1	13.61	2.3
	55	61	1	53.90	9.1
* AREA OF ABOVE SUBDIVISION 55 IS 593.66					
NORFOLK	56 01	11	1	471.00	90.6
	56 01	61	2	49.11	9.4
* AREA OF ABOVE SUBDIVISION 56 01 IS 520.11					
NORFOLK	56 02	11	1	308.88	77.8
	56 02	12	1	85.11	21.4
	56 02	61	1	3.10	0.8
* AREA OF ABOVE SUBDIVISION 56 02 IS 397.08					
NORFOLK	57 01	11	3	298.89	54.0
	57 01	12	3	188.22	34.0
	57 01	15	2	66.72	12.0
* AREA OF ABOVE SUBDIVISION 57 01 IS 553.69					

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA	CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
NORFOLK	57 02		11	1	333.45	75.4
	57 02		12	1	38.96	8.8
	57 02		15	2	28.11	6.4
	57 02		16	1	13.68	3.1
	57 02		54	1	0.07	0.0
	57 02		61	1	28.11	6.4
* AREA OF ABOVE SUBDIVISION	57 02	IS	442.38			
NORFOLK	58		11	2	175.63	48.7
	58		12	3	85.99	23.8
	58		15	1	14.76	4.1
	58		16	1	21.23	5.9
	58		19	1	63.29	17.5
* AREA OF ABOVE SUBDIVISION	58	IS	361.10			
NORFOLK	59 01		11	4	197.37	52.5
	59 01		12	3	5.39	1.4
	59 01		15	3	26.69	7.1
	59 01		16	1	44.42	11.8
	59 01		19	1	101.78	27.1
* AREA OF ABOVE SUBDIVISION	59 01	IS	375.72			
NORFOLK	59 02		11	3	396.35	78.3
	59 02		12	1	88.99	17.6
	59 02		15	2	20.83	4.1
* AREA OF ABOVE SUBDIVISION	59 02	IS	506.10			
NORFOLK	59 03		11	1	286.70	81.6

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	59 03	12	4	8,63	2,5
	59 03	15	1	13,08	3,7
	59 03	16	1	24,07	6,9
	59 03	19	1	18,74	5,3
* AREA OF ABOVE SUBDIVISION 59 03 IS 351,22					
NORFOLK	60	11	1	341,80	83,6
	60	16	1	1,08	0,3
	60	61	1	65,73	16,1
* AREA OF ABOVE SUBDIVISION 60 IS 408,61					
NORFOLK	61	11	3	506,00	62,1
	61	12	3	208,03	25,5
	61	13	2	0,54	0,1
	61	16	2	55,16	6,8
	61	54	1	0,54	0,1
	61	61	4	45,17	5,5
* AREA OF ABOVE SUBDIVISION 61 IS 815,44					
NORFOLK	62	11	1	510,59	91,1
	62	12	1	13,76	2,5
	62	13	1	30,55	5,5
	62	16	1	1,82	0,3
	62	19	5	1,75	0,3
	62	54	3	1,89	0,3
* AREA OF ABOVE SUBDIVISION 62 IS 560,36					
NORFOLK	63	11	2	6,47	1,1

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	63	12	3	188.31	32.4
	63	13	1	385.51	66.4
	63	54	2	0.27	0.0
* AREA OF ABOVE SUBDIVISION 63 IS 580.70					
NORFOLK	64	11	1	442.94	59.7
	64	12	1	62.67	8.4
	64	13	3	49.85	6.7
	64	16	1	32.11	4.3
	64	19	1	30.83	4.2
	64	41	1	9.04	1.2
	64	54	4	114.49	15.4
* AREA OF ABOVE SUBDIVISION 64 IS 741.92					
NORFOLK	65 01	11	3	194.16	83.3
	65 01	54	2	25.20	10.8
	65 01	61	1	13.68	5.9
* AREA OF ABOVE SUBDIVISION 65 01 IS 232.96					
NORFOLK	65 02	11	1	205.35	60.7
	65 02	12	1	35.84	10.6
	65 02	19	1	58.66	17.4
	65 02	54	8	38.20	11.3
* AREA OF ABOVE SUBDIVISION 65 02 IS 338.08					
NORFOLK	66 01	11	1	141.09	79.7
	66 01	12	1	14.42	8.1
	66 01	61	2	21.63	12.2
* AREA OF ABOVE SUBDIVISION 66 01 IS 177.14					

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PRESENT LAND USE BY CENSUS DIVISION
AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
NORFOLK	66 02	11	3	285.48	71.8
	66 02	12	1	38.86	9.8
	66 02	16	1	27.22	6.8
	66 02	19	1	23.51	5.9
	66 02	61	3	22.50	5.7
* AREA OF ABOVE SUBDIVISION 66 02 IS 397.60					
NORFOLK	66 03	11	1	263.54	73.2
	66 03	12	2	36.25	9.4
	66 03	16	1	22.91	5.9
	66 03	54	1	44.27	11.4
	66 03	61	1	0.13	0.0
* AREA OF ABOVE SUBDIVISION 66 03 IS 387.10					
NORFOLK	66 04	11	1	189.34	76.3
	66 04	12	1	20.96	8.4
	66 04	16	1	0.13	0.1
	66 04	54	2	37.60	15.2
* AREA OF ABOVE SUBDIVISION 66 04 IS 248.02					
NORFOLK	66 05	11	4	385.47	64.6
	66 05	12	2	106.40	17.8
	66 05	41	1	4.38	0.7
	66 05	54	3	100.14	16.8
* AREA OF ABOVE SUBDIVISION 66 05 IS 596.40					
NORFOLK	66 06	11	2	374.03	65.4
	66 06	12	4	134.85	23.6

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	66 06	19	2	3.03	0.5
	66 06	41	1	36.06	6.3
	66 06	54	2	16.58	2.9
	66 06	61	2	6.94	1.2
* AREA OF ABOVE SUBDIVISION 66 06 IS 571.63					
NORFOLK	66 07	11	3	350.65	58.3
	66 07	12	2	82.65	13.7
	66 07	15	1	1.01	0.2
	66 07	19	1	0.81	0.1
	66 07	41	3	103.33	17.2
	66 07	54	1	47.38	7.9
	66 07	61	1	16.11	2.7
* AREA OF ABOVE SUBDIVISION 66 07 IS 601.87					
NORFOLK	67	11	2	1.48	0.1
	67	11	3	105.26	5.6
	67	12	4	87.46	4.6
	67	15	3	571.64	30.2
	67	16	2	201.62	10.6
	67	19	2	361.41	19.1
	67	20	4	17.94	0.9
	67	21	2	105.23	5.6
	67	41	2	269.09	14.2
	67	52	1	20.23	1.1
	67	54	3	153.47	8.1
* AREA OF ABOVE SUBDIVISION 67 IS 1894.75					

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
NORFOLK	68	11	2	70,27	18,4
	68	11	1	161,67	42,3
	68	12	2	42,35	11,1
	68	16	1	26,84	7,0
	68	20	1	21,92	5,7
	68	21	4	46,35	12,1
	68	41	1	12,88	3,4
* AREA OF ABOVE SUBDIVISION 68 IS 382,48					
NORFOLK	69 01	11 -	1	75,60	7,3
	69 01	11	4	222,07	21,3
	69 01	12	5	441,13	42,4
	69 01	15	5	48,64	4,7
	69 01	16	1	34,00	3,3
	69 01	19	3	41,75	4,0
	69 01	21	2	178,29	17,1
* AREA OF ABOVE SUBDIVISION 69 01 IS 1041,54					
NORFOLK	69 02	61'	1	47,84	6,6
	69 02	11	2	331,20	45,8
	69 02	12	1	64,09	8,9
	69 02	15	4	94,45	13,1
	69 02	16	1	32,11	4,4
	69 02	19	3	52,76	7,3
	69 02	21	2	79,01	10,9
	69 02	54	2	21,52	3,0
* AREA OF ABOVE SUBDIVISION 69 02 IS 723,05					

PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
NORFOLK	70 01	11	4	87.48	23.6
	70 01	12	4	85.46	23.0
	70 01	13	4	1.15	0.3
	70 01	19	1	149.52	40.3
	70 01	54	1	47.41	12.8
* AREA OF ABOVE SUBDIVISION 70 01 IS 370.87					
NORFOLK	70 02	11	1	524.51	67.4
	70 02	12	2	58.41	7.5
	70 02	13	1	0.13	0.0
	70 02	15	1	20.51	2.6
	70 02	19	1	44.19	5.7
	70 02	54	2	130.47	16.8
* AREA OF ABOVE SUBDIVISION 70 02 IS 778.16					
PORTSMOUTH	101	11	3	34.94	4.8
	101	12	1	33.86	4.7
	101	15	1	315.61	43.7
	101	19	1	19.70	2.7
	101	54	1	318.76	44.1
* AREA OF ABOVE SUBDIVISION 101 IS 722.87					
PORTSMOUTH	102	11	1	206.55	51.5
	102	12	1	24.82	6.2
	102	54	2	169.56	42.3
* AREA OF ABOVE SUBDIVISION 102 IS 400.94					
PORTSMOUTH	103	11	1	308.56	62.3

PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA	CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	103		12	1	0.13	0.0
	103		16	1	62.68	12.7
	103		54	2	123.71	25.0
* AREA OF ABOVE SUBDIVISION	103	IS	495.08			
PORTSMOUTH	104		11	1	205.64	50.0
	104		12	1	14.37	3.5
	104		16	3	2.16	0.5
	104		54	1	188.96	46.0
* AREA OF ABOVE SUBDIVISION	104	IS	411.20			
PORTSMOUTH	105		11	3	77.59	32.6
	105		12	2	153.42	64.5
	105		15	2	0.61	0.3
	105		16	1	6.34	2.7
* AREA OF ABOVE SUBDIVISION	105	IS	237.96			
PORTSMOUTH	106		11	1	196.93	63.0
	106		12	2	4.18	1.3
	106		15	2	41.63	13.3
	106		19	1	2.56	0.8
	106		54	2	67.12	21.5
* AREA OF ABOVE SUBDIVISION	106	IS	312.42			
PORTSMOUTH	107		11	1	125.41	63.3
	107		12	1	0.54	0.3
	107		16	1	3.44	1.7
	107		19	2	56.13	28.3

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA	CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	107		54	1	12.68	6.4
AREA OF ABOVE SUBDIVISION	107	IS	198.21			
PORTSMOUTH	108		11	1	12.28	4.6
	108		16	1	97.75	36.6
	108		54	2	156.77	58.8
* AREA OF ABOVE SUBDIVISION	108	IS	266.80			
PORTSMOUTH	109		11	2	65.24	28.7
	109		12	1	12.68	5.6
	109		16	2	6.34	2.8
	109		19	1	30.56	13.5
	109		54	1	112.13	49.4
* AREA OF ABOVE SUBDIVISION	109	IS	226.95			
PORTSMOUTH	110		11	2	48.04	25.6
	110		12	1	60.05	32.0
	110		15	1	3.64	1.9
	110		16	1	49.52	26.4
	110		19	1	1.35	0.7
	110		54	1	24.90	13.3
* AREA OF ABOVE SUBDIVISION	110	IS	187.50			
PORTSMOUTH	111		11	1	79.42	88.0
	111		12	1	5.33	5.9
	111		15	1	5.47	6.1
* AREA OF ABOVE SUBDIVISION	111	IS	90.21			
PORTSMOUTH	112		11	1	8.43	7.5

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA	CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	112		12	1	9[illegible],92	83,9
	112		15	1	0,20	0,2
	112		19	1	9,45	8,4
* AREA OF ABOVE SUBDIVISION	112	IS	111,93			
PORTSMOUTH	113		11	2	47,10	21,5
	113		12	4	117,94	53,9
	113		15	2	53,71	24,5
* AREA OF ABOVE SUBDIVISION	113	IS	218,81			
PORTSMOUTH	114		11	2	153,71	63,2
	114		12	2	33,20	13,6
	114		15	1	0,68	0,4
	114		16	1	55,60	22,8
* AREA OF ABOVE SUBDIVISION	114	IS	243,39			
PORTSMOUTH	115		11	2	124,16	42,3
	115		12	2	169,37	57,6
	115		16	2	0,27	0,1
* AREA OF ABOVE SUBDIVISION	115	IS	293,87			
PORTSMOUTH	116		11	2	577,42	75,0
	116		12	3	64,25	8,3
	116		15	10	1,21	0,2
	116		54	1	99,86	13,0
	116		61	1	27,20	3,5
AREA OF ABOVE SUBDIVISION	116	IS	769,87			
PORTSMOUTH	117		11	4	413,52	71,7

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	117	12	3	29.36	5.1
	117	15	2	127.55	22.1
	117	19	1	6.01	1.0
AREA OF ABOVE SUBDIVISION 117		IS 576.43			
PORTSMOUTH	118	11	3	252.98	75.8
	118	12	1	29.62	8.9
	118	15	3	34.35	10.3
	118	41	1	16.67	5.0
* AREA OF ABOVE SUBDIVISION 118		IS 333.62			
PORTSMOUTH	119	11	1	279.20	91.8
	119	13	1	0.81	0.3
	119	19	1	24.09	7.9
* AREA OF ABOVE SUBDIVISION 119		IS 304.10			
PORTSMOUTH	120	11	1	137.47	76.0
	120	15	1	17.81	9.8
	120	16	1	25.65	14.2
* AREA OF ABOVE SUBDIVISION 120		IS 180.92			
PORTSMOUTH	121	11	2	217.43	85.2
	121	12	1	15.99	6.3
	121	15	1	16.26	6.4
	121	16	2	5.53	2.2
* AREA OF ABOVE SUBDIVISION 121		IS 255.21			
PORTSMOUTH	122	11	6	61.21	5.7
	122	13	1	757.33	71.0

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	122	16	1	63,84	6,0
	122	19	1	27,60	2,6
	122	54	3	156,16	14,6
* AREA OF ABOVE SUBDIVISION 122 IS 1066,16					
PORTSMOUTH	123	11	1	417,67	72,9
	123	12	1	13,17	2,3
	123	13	7	28,69	5,0
	123	16	5	82,77	14,5
	123	54	1	30,45	5,3
* AREA OF ABOVE SUBDIVISION 123 IS 572,74					
PORTSMOUTH	124	11	3	341,96	69,4
	124	12	1	46,45	9,4
	124	13	4	27,61	5,6
	124	16	1	20,86	4,2
	124	19	4	44,28	9,0
	124	21	1	11,55	2,3
* AREA OF ABOVE SUBDIVISION 124 IS 492,63					
PORTSMOUTH	125	11	6	282,25	45,9
	125	12	1	117,88	19,2
	125	16	1	0,95	0,2
	125	19	2	211,23	34,3
	125	21	1	0,07	0,0
	125	41	1	2,84	0,5
* AREA OF ABOVE SUBDIVISION 125 IS 615,13					

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PRESENT LAND USE BY CENSUS DIVISION
AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
PORTSMOUTH	126	11	1	366,18	68,4
	126	12	2	121,90	22,8
	126	15	2	3,96	0,7
	126	16	1	13,10	2,4
	126	19	1	0,34	0,1
	126	41	1	29,43	5,5
* AREA OF ABOVE SUBDIVISION 126 IS 534,99					
PORTSMOUTH	127 01	11	2	397,17	37,7
	127 01	12	6	66,49	6,3
	127 01	13	1	4,46	0,4
	127 01	16	2	123,87	11,8
	127 01	21	1	30,99	2,9
	127 01	41	2	49,76	4,7
	127 01	42	2	281,10	26,7
	127 01	53	1	99,18	9,4
* AREA OF ABOVE SUBDIVISION 127 01 IS 1053,01					
PORTSMOUTH	127 02	11	1	396,04	91,4
	127 02	12	3	15,60	3,6
	127 02	16	1	3,38	0,8
	127 02	19	4	15,12	3,5
	127 02	21	3	2,97	0,7
* AREA OF ABOVE SUBDIVISION 127 02 IS 433,10					
PORTSMOUTH	128	11	1	939,79	60,7
	128	12	2	182,17	11,6

PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	128	16	1	56.97	3.7
	128	19	1	155.23	10.0
	128	42	1	90.25	5.8
	128	53	1	34.09	2.2
	128	54	1	73.30	4.7
	128	61	2	16.94	1.1
* AREA OF ABOVE SUBDIVISION 128	IS	1548.73			
PORTSMOUTH	129	11	3	847.83	63.6
	129	12	1	24.50	1.8
	129	19	1	171.32	12.8
	129	54	1	270.36	20.3
	129	61	3	19.91	1.5
* AREA OF ABOVE SUBDIVISION 129	IS	1333.92			
PORTSMOUTH	130	11	3	1317.85	12.7
	130	12	2	3.44	0.0
	130	13	2	459.43	4.4
	130	14	1	1.01	0.0
	130	15	1	38.98	0.4
	130	16	1	41.41	0.4
	130	17	2	209.06	2.0
	130	19	1	297.01	2.9
	130	21	8	1192.72	11.5
	130	41	5	338.30	3.2
	130	42	2	89.53	0.9

PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	130	54	2	3752,21	36,0
	130	55	1	1905,60	18,3
	130	61	2	116,59	1,1
	130	62	3	649,55	6,2
* AREA OF ABOVE SUBDIVISION 130 IS 10412,54					
PORTSMOUTH	131	11	6	690,75	19,5
	131	12	1	63,46	1,8
	131	13	1	5,06	0,1
	131	14	1	44,57	1,3
	131	16	3	5,13	0,1
	131	17	1	60,80	1,7
	131	21	5	754,31	21,2
	131	41	5	426,97	12,0
	131	42	2	90,26	2,5
	131	54	1	1154,77	32,5
	131	55	7	37,74	1,1
	131	61	4	168,97	5,3
	131	62	1	26,95	0,8
* AREA OF ABOVE SUBDIVISION 131 IS 3549,79					
CHESAPEAKE	200 01	11	1	282,26	57,4
	200 01	12	1	42,38	8,6
	200 01	54	1	166,79	33,9
* AREA OF ABOVE SUBDIVISION 200 01 IS 491,43					
CHESAPEAKE	200 03	11	2	590,71	[illegible]

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	200 03	12	1	27.47	3.8
	200 03	16	1	21.94	3.0
	200 03	54	1	39.75	5.5
	200 03	61	1	40.90	5.7
* AREA OF ABOVE SUBDIVISION 200 03 IS 720.76					
CHESAPEAKE	201 + 200.02	11	1	725.36	73.0
	201 + 200.02	12	2	52.10	5.2
	201 + 200.02	13	1	82.66	8.3
	201 + 200.02	15	1	5.47	0.6
	201 + 200.02	16	2	33.81	3.4
	201 + 200.02	21	1	14.51	1.5
	201 + 200.02	23	1	6.82	0.7
	201 + 200.02	54	4	56.28	5.7
	201 + 200.02	61	1	16.60	1.7
AREA OF ABOVE SUBDIVISION 201 + 200.02 993.62					
CHESAPEAKE	202	11	1	457.07	76.3
	202	12	1	29.56	4.9
	202	15	2	65.07	10.9
	202	16	3	23.49	3.9
	202	23	1	24.03	4.0
* AREA OF ABOVE SUBDIVISION 202 IS 599.21					
CHESAPEAKE	203	11	2	195.76	68.9
	203	12	2	28.61	10.2
	203	13	1	28.21	10.0

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	203	16	1	30.50	10.9
* AREA OF ABOVE SUBDIVISION 203 IS 281.09					
CHESAPEAKE	204	11	1	197.50	46.6
	204	13	1	121.03	28.6
	204	16	1	50.22	11.9
	204	42	3	44.69	10.6
	204	54	2	9.79	2.4
* AREA OF ABOVE SUBDIVISION 204 IS 423.42					
CHESAPEAKE	205 01	13	4	607.51	54.8
	205 01	15	1	5.67	0.5
	205 01	16	1	0.34	0.0
	205 01	19	1	14.38	1.3
	205 01	41	1	25.93	2.3
	205 01	42	1	15.39	1.4
	205 01	54	1	439.68	39.6
* AREA OF ABOVE SUBDIVISION 205 01 IS 1108.97					
CHESAPEAKE	205 02	11	1	119.64	25.6
	205 02	13	3	134.36	28.8
	205 02	15	1	14.18	3.0
	205 02	16	1	23.77	5.1
	205 02	19	2	56.31	12.1
	205 02	41	1	42.14	9.0
	205 02	42	1	60.35	12.9
	205 02	54	3	9.86	2.1

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	205 02	61	1	6.48	1.4
* AREA OF ABOVE SUBDIVISION 205 02 IS 467.09					
CHESAPEAKE	206	11	2	488.07	64.4
	206	13	1	27.89	3.7
	206	15	4	89.16	11.8
	206	16	4	69.81	9.2
	206	21	2	6.35	0.8
	206	41	2	48.41	6.4
	206	42	1	0.81	0.1
	206	61	1	27.89	3.7
* AREA OF ABOVE SUBDIVISION 206 IS 758.41					
CHESAPEAKE	207	11	10	418.95	40.0
	207	13	2	55.09	5.3
	207	15	4	27.28	2.6
	207	16	2	24.03	2.3
	207	19	1	14.65	1.4
	207	21	4	188.60	18.0
	207	41	4	261.37	24.9
	207	42	1	20.53	2.0
	207	61	1	38.15	3.6
* AREA OF ABOVE SUBDIVISION 207 IS 1048.58					
CHESAPEAKE	208 01	11	2	484.69	45.1
	208 01	12	1	0.07	0.0
	208 01	16	2	46.24	4.3

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	208 01	19	2	69,94	6,5
	208 01	21	4	326,27	30,4
	208 01	41	3	82,77	7,7
	208 01	53	1	[illegible],17	1,8
	208 01	61	1	45,29	4,2
* AREA OF ABOVE SUBDIVISION 208 01 IS 1074,44					
CHESAPEAKE	208 02	15	1	11,02	0,1
	208 02	11	5	221,86	1,5
	208 02	12	1	7,10	0,0
	208 02	15	1	35,19	0,2
	208 02	16	1	1,42	0,0
	208 02	17	4	242,15	1,6
	208 02	19	1	52,84	0,4
	208 02	21	12	5787,90	39,0
	208 02	41	17	8005,75	53,9
	208 02	42	2	83,80	0,6
	208 02	51	4	6,02	0,0
	208 02	53	3	51,67	0,3
	208 02	61	3	343,59	2,3
* AREA OF ABOVE SUBDIVISION 208 02 IS 14850,24					
CHESAPEAKE	209 01	11	4	324,00	15,3
	209 01	12	1	23,51	1,1
	209 01	15	3	134,14	6,3
	209 01	16	1	11,15	0,5

	208 02	11	5	221.86	1.5
	208 02	12	1	7.10	0.0
	208 02	15	1	35.19	0.2
	208 02	16	1	1.42	0.0
	208 02	17	4	242.15	1.6
	208 02	19	1	52.84	0.4
	208 02	21	12	5787.90	3[illegible].0
	208 02	41	17	8005.75	53.9
	208 02	42	2	83.80	0.6
	208 02	51	4	6.02	0.0
	208 02	53	3	51.67	0.3
	208 02	61	3	343.59	2.3
* AREA OF ABOVE SUBDIVISION 208 02 IS 14850.24					
CHESAPEAKE	209 01	11	4	324.00	15.3
	209 01	12	1	23.51	1.1
	209 01	15	3	134.14	6.3
	209 01	16	1	11.15	0.5

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	209 01	17	2	47.64	2.2
	209 01	21	8	914.53	43.2
	209 01	41	10	633.91	29.9
	209 01	53	1	28.71	1.4
* AREA OF ABOVE SUBDIVISION 209 01 IS 2117.59					
CHESAPEAKE	209 02	15	1	18.86	0.5
	209 02	11	5	476.69	12.0
	209 02	12	3	79.25	2.0
	209 02	13	2	169.88	4.3
	209 02	15	3	69.84	1.8
	209 02	16	1	55.12	1.4
	209 02	17	2	77.17	1.9
	209 02	19	3	2[illegible]4.76	7.2
	209 02	21	5	655.32	16.5
	209 02	41	5	1229.74	31.0

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	209 01	17	2	47.64	2.2
	209 01	21	8	914.53	43.2
	209 01	41	10	633.91	29.9
	209 01	53	1	28.71	1.4
* AREA OF ABOVE SUBDIVISION 209 01 IS 2117.59					
CHESAPEAKE	209 02	15	1	18.86	0.5
	209 02	11	5	476.69	12.0
	209 02	12	3	79.25	2.0
	209 02	13	2	169.88	4.3
	209 02	15	3	69.84	1.8
	209 02	16	1	55.12	1.4
	209 02	17	2	77.17	1.9
	209 02	19	3	284.76	7.2
	209 02	21	5	655.32	16.5
	209 02	41	5	1229.74	31.0
	209 02	42	1	26.35	0.7
	209 02	54	6	320.39	8.1
	209 02	61	4	454.35	11.5
	209 02	62	1	43.70	1.1
* AREA OF ABOVE SUBDIVISION 209 02 IS 3961.41					
CHESAPEAKE	210 01	15	5	5.54	0.1
	210 01	11	4	269.20	5.8
	210 01	12	4	53.06	1.1
	210 01	13	1	50.15	1.1

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	210 01	16	2	66,79	1,4
	210 01	17	4	303,40	7,8
	210 01	19	12	106,61	2,3
	210 01	21	8	1101,68	23,8
	210 01	41	10	2030,32	43,9
	210 01	42	1	164,65	3,6
	210 01	51	1	15,21	0,3
	210 01	58	1	65,83	1,4
	210 01	61	8	335,19	7,2
* AREA OF ABOVE SUBDIVISION 210 01 IS 4633,66					
CHESAPEAKE	210 02	11	3	383,77	3,3
	210 02	12	1	8,30	0,1
	210 02	16	2	92,55	0,8
	210 02	17	8	421,21	3,6
	210 02	19	4	91,62	0,8
	210 02	21	15	4876,75	41,4
	210 02	41	13	5547,33	47,1
	210 02	42	3	344,69	2,9
* AREA OF ABOVE SUBDIVISION 210 02 IS 11766,36					
CHESAPEAKE	211 01	15	3	0,54	0,0
	211 01	11	2	146,76	0,4
	211 01	12	1	63,80	0,2
	211 01	15	1	494,20	1,2
	211 01	16	2	41,17	0,1

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	211	17	11	404.08	1.0
	211	19	1	60.44	0.1
	211	21	21	22210.72	54.9
	211	41	46	14711.46	36.4
	211	42	6	885.50	2.2
	211	51	1	420.74	1.0
	211	54	1	303.54	0.8
	211	61	8	703.65	1.7
* AREA OF ABOVE SUBDIVISION 211	IS 40446.14				
CHESAPEAKE	212	16	1	1159.85	2.6
	212	17	1	18.95	0.0
	212	21	35	12543.01	28.1
	212	41	9	30760.00	68.9
	212	42	4	49.04	0.1
	212	54	1	84.15	0.2
* AREA OF ABOVE SUBDIVISION 212	IS 44614.70				
CHESAPEAKE	213 01	11	2	41.67	0.1
	213 01	12	2	19.93	0.0
	213 01	15	1	3.04	0.0
	213 01	17	5	232.24	0.4
	213 01	21	19	4742.34	7.8
	213 01	41	8	49390.56	81.0
	213 01	42	10	3523.50	5.8
	213 01	52	1	2900.53	4.8

LAND MANAGEMENT INFORMATION SYSTEMS ENVIRONMENT CANADA DATA SOURCE: U.S. GEOLOGICAL SURVEY

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P R E S E N T L A N D U S E B Y C E N S U S D I V I S I O N A N D S U B D I V I S I O N

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	213 01	53	1	50.60	0.1
	213 01	54	13	5.49	0.0
	213 01	61	1	46.35	0.1
* AREA OF ABOVE SUBDIVISION 213 01 IS 60956.05					
CHESAPEAKE	213 02	11	4	52.00	0.4
	213 02	12	3	8.51	0.1
	213 02	13	3	33.59	0.2
	213 02	16	5	127.45	0.9
	213 02	17	9	704.50	4.8
	213 02	19	2	68.53	0.5
	213 02	21	15	6742.41	45.5
	213 02	41	28	5763.89	38.9
	213 02	42	5	524.73	3.5
	213 02	54	1	335.77	2.3
	213 02	61	7	456.68	3.1
* AREA OF ABOVE SUBDIVISION 213 02 IS 14815.95					
CHESAPEAKE	214 01	15	1	34.45	3.5
	214 01	16	2	27.09	2.7
	214 01	17	6	68.70	6.9
	214 01	21	1	602.61	60.8
	214 01	41	4	207.16	20.9
	214 01	42	2	37.96	3.8
	214 01	61	4	13.78	1.4
* AREA OF ABOVE SUBDIVISION 214 01 IS 991.82					

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
CHESAPEAKE	214 02	11	5	388.66	19.6
	214 02	12	3	111.11	5.6
	214 02	13	1	162.44	8.2
	214 02	15	1	18.44	0.9
	214 02	16	4	42.02	2.1
	214 02	17	2	70.19	3.5
	214 02	19	3	145.22	7.3
	214 02	21	3	494.06	24.9
	214 02	41	5	398.66	20.1
	214 02	42	2	90.57	4.6
	214 02	54	15	61.47	3.1
	214 02	61	1	3.85	0.2
* AREA OF ABOVE SUBDIVISION 214 02 IS 1986.88					
CHESAPEAKE	214 03	11	3	623.08	34.2
	214 03	12	3	158.97	8.7
	214 03	16	2	601.19	33.0
	214 03	19	2	113.26	6.2
	214 03	41	1	37.21	2.0
	214 03	54	3	247.01	13.6
	214 03	62	1	40.99	2.3
* AREA OF ABOVE SUBDIVISION 214 03 IS 1821.70					
CHESAPEAKE	214 04	11	14	384.41	12.9
	214 04	12	4	103.59	3.5
	214 04	13	1	39.03	1.3

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	214 04	15	1	169,48	5,7
	214 04	16	1	1,89	0,1
	214 04	17	1	4,39	0,1
	214 04	19	3	118,77	4,0
	214 04	21	8	649,37	21,8
	214 04	41	5	1242,78	41,7
	214 04	42	1	223,12	7,5
	214 04	53	3	44,30	1,5
* AREA OF ABOVE SUBDIVISION 214 04 IS		2981,06			
CHESAPEAKE	215 01	11	3	255,52	5,3
	215 01	15	1	126,11	2,7
	215 01	16	2	46,85	1,0
	215 01	17	3	221,36	4,6
	215 01	19	1	116,86	2,4
	215 01	21	8	2018,39	41,8
	215 01	41	6	1825,73	37,7
	215 01	54	1	56,44	1,2
	215 01	61	2	104,32	3,4
* AREA OF ABOVE SUBDIVISION 215 01 IS		4831,61			
CHESAPEAKE	215 02	11	2	416,73	12,3
	215 02	16	1	16,87	0,5
	215 02	17	3	407,85	12,1
	215 02	19	1	30,24	0,9
	215 02	21	5	1344,96	39,7

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	215 02	41	7	1015.22	30.0
	215 02	54	1	90.29	2.7
	215 02	61	5	61.67	1.8
* AREA OF ABOVE SUBDIVISION 215 02 IS 3383.83					
CHESAPEAKE	216	11	5	724.72	23.2
	216	12	1	1.96	0.1
	216	16	3	55.50	1.8
	216	19	3	310.42	10.0
	216	21	5	853.59	27.4
	216	41	6	834.33	26.7
	216	42	1	39.32	1.3
	216	54	6	269.46	8.6
	216	61	2	30.25	1.0
* AREA OF ABOVE SUBDIVISION 216 IS 3119.38					
VA. BEACH	400	11	4	32.62	1.3
	400	12	1	90.64	3.7
	400	15	1	16.37	0.7
	400	16	2	1338.96	54.1
	400	19	3	243.31	9.8
	400	21	1	10.24	0.4
	400	41	7	199.54	8.1
	400	52	1	71.02	2.9
	400	54	15	468.31	18.9
	400	74	1	2.43	0.1
* AREA OF ABOVE SUBDIVISION 400 IS 2473.43					

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
VA. BEACH	402	11	4	188.40	15.2
	402	12	3	51.04	4.1
	402	16	3	72.42	5.9
	402	19	7	364.17	2[illegible].4
	402	21	3	384.24	31.1
	402	41	2	137.44	11.1
	402	53	3	39.71	3.2
* AREA OF ABOVE SUBDIVISION 402 IS 1237.41					
VA. BEACH	404	11	4	358.08	14.9
	404	12	1	37.69	1.6
	404	16	5	53.79	2.2
	404	17	2	10.39	0.4
	404	19	1	49.91	2.1
	404	21	5	1158.65	48.2
	404	41	5	590.90	24.6
	404	53	1	145.94	6.1
* AREA OF ABOVE SUBDIVISION 404 IS 2405.48					
VA. BEACH	406	11	1	239.13	30.0
	406	12	2	55.86	7.0
	406	15	2	11.87	1.5
	406	16	1	50.11	6.3
	406	17	1	23.74	3.0
	406	19	2	7.55	0.9
	406	21	8	138.68	17.4

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	406	41	5	179.84	22.6
	406	53	1	23.75	3.0
	406	75	1	66.16	8.3
* AREA OF ABOVE SUBDIVISION 406	IS	796.48			
VA. BEACH	408	11	8	531.51	53.0
	408	12	3	32.92	3.3
	408	16	2	18.34	1.8
	408	19	2	78.85	7.9
	408	21	6	200.04	20.0
	408	22	1	22.05	2.2
	408	41	3	117.43	11.7
	408	54	1	1.08	0.1
* AREA OF ABOVE SUBDIVISION 408	IS	1002.29			
VA. BEACH	410	11	6	933.08	60.6
	410	12	3	267.02	17.3
	410	15	2	15.92	1.0
	410	16	1	28.26	1.8
	410	19	3	76.17	4.9
	410	21	3	58.49	3.8
	410	22	1	62.05	4.0
	410	41	1	33.33	2.2
	410	54	1	66.30	4.3
* AREA OF ABOVE SUBDIVISION 410	IS	1540.54			
VA. BEACH	412	11	3	863.89	49.5

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	412	12	3	26.50	1.5
	412	15	1	16.31	0.9
	412	16	3	55.75	3.2
	412	19	1	12.00	0.7
	412	21	6	190.01	10.9
	412	41	4	450.65	25.8
	412	53	2	130.10	7.5
* AREA OF ABOVE SUBDIVISION 412 IS 1745.21					
VA. BEACH	414	11	2	754.22	41.6
	414	12	2	16.99	0.9
	414	15	1	3.30	0.2
	414	16	1	7.01	0.4
	414	21	5	602.84	33.2
	414	41	2	139.63	7.7
	414	53	1	26.90	1.5
	414	54	2	260.55	14.4
	414	61	1	2.49	0.1
* AREA OF ABOVE SUBDIVISION 414 IS 1813.93					
VA. BEACH	416	11	3	260.25	23.2
	416	12	1	9.84	0.9
	416	16	2	25.09	2.2
	416	19	1	9.24	0.8
	416	21	2	448.38	40.0
	416	22	3	3.17	0.3

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	416	41	3	159.01	14.2
	416	53	1	21.31	1.9
	416	54	2	184.50	16.5
* AREA OF ABOVE SUBDIVISION 416 IS 1120.78					
VA. BEACH	418	11	2	121.25	6.9
	418	12	2	168.02	9.5
	418	15	1	10.04	0.6
	418	16	2	746.86	42.3
	418	21	4	52.37	3.0
	418	41	2	246.40	13.9
	418	52	3	85.99	4.9
	418	53	2	20.76	1.2
	418	54	30	93.21	5.3
	418	61	2	69.43	3.9
	418	74	1	152.10	8.6
* AREA OF ABOVE SUBDIVISION 418 IS 1766.43					
VA. BEACH	420	11	1	266.00	13.1
	420	21	4	181.78	9.0
	420	41	2	955.05	47.1
	420	42	1	46.59	2.3
	420	54	1	577.94	28.5
* AREA OF ABOVE SUBDIVISION 420 IS 2027.36					
VA. BEACH	422	11	2	869.35	45.0
	422	12	1	0.07	0.0

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	422	16	2	50.72	2.6
	422	21	3	138.67	7.2
	422	41	4	635.15	32.9
	422	52	1	15.76	0.8
	422	54	5	220.73	11.4
* AREA OF ABOVE SUBDIVISION 422 IS 1930.48					
VA. BEACH	424	11	1	557.47	85.6
	424	12	2	25.23	3.9
	424	21	2	64.50	9.9
	424	41	4	4.05	0.6
* AREA OF ABOVE SUBDIVISION 424 IS 651.25					
VA. BEACH	426	11	2	404.23	53.7
	426	12	3	127.04	16.9
	426	15	1	3.17	0.4
	426	21	4	85.07	11.3
	426	41	4	85.41	11.3
	426	54	1	47.69	6.3
* AREA OF ABOVE SUBDIVISION 426 IS 752.62					
VA. BEACH	428	11	6	673.98	56.1
	428	12	1	10.59	0.9
	428	15	1	23.41	1.9
	428	16	1	24.16	2.0
	428	17	1	25.64	2.1
	428	19	1	168.65	14.0

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	428	21	2	83.40	6.9
	428	41	4	165.92	13.8
	428	42	1	25.57	2.1
* AREA OF ABOVE SUBDIVISION 428 IS 1201.32					
VA. BEACH	430	53	2	13.92	0.3
	430	11	3	687.01	16.2
	430	12	1	98.86	2.3
	430	16	1	21.91	0.5
	430	19	2	311.58	7.3
	430	21	4	753.64	17.7
	430	41	5	760.65	17.9
	430	42	1	76.09	1.8
	430	54	7	1313.60	30.9
	430	61	3	135.69	3.2
	430	74	2	77.50	1.8
* AREA OF ABOVE SUBDIVISION 430 IS 4247.44					
VA BEACH	432	11	2	84.84	1.8
	432	15	1	43.26	0.9
	432	16	1	662.85	14.4
	432	19	1	100.80	2.2
	432	41	1	3459.06	75.2
	432	54	28	76.76	1.7
	432	74	2	172.75	3.8
* AREA OF ABOVE SUBDIVISION 432 IS 4600.30					

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
VA. BEACH	434	11	1	243.39	64.2
	434	41	5	61.06	16.1
	434	54	12	12.20	3.2
	434	74	1	62.41	16.5
* AREA OF ABOVE SUBDIVISION 434 IS 379.06					
VA. BEACH	436	11	1	308.65	82.4
	436	41	2	20.16	5.4
	436	53	3	17.67	4.7
	436	54	7	6.14	1.6
	436	74	1	22.11	5.9
* AREA OF ABOVE SUBDIVISION 436 IS 374.73					
VA. BEACH	438	11	4	564.41	45.2
	438	16	1	39.78	3.2
	438	19	1	259.91	20.8
	438	41	5	206.80	16.6
	438	53	1	44.16	3.5
	438	54	18	128.92	10.3
	438	74	1	3.91	0.3
* AREA OF ABOVE SUBDIVISION 438 IS 1247.97					
VA. BEACH	440	11	6	822.93	44.4
	440	12	2	404.55	21.8
	440	15	3	10.12	0.5
	440	16	3	1.35	0.1
	440	19	1	25.17	1.4

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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	440	41	3	367.59	19.8
	440	53	2	31.57	1.7
	440	54	9	109.17	5.9
	440	74	1	81.59	4.4
* AREA OF ABOVE SUBDIVISION 440		IS 1853.96			
VA. BEACH	442	11	9	145.19	8.6
	442	12	2	74.66	4.4
	442	14	1	1.35	0.1
	442	15	1	25.57	1.5
	442	16	1	34.81	2.1
	442	17	2	53.51	3.2
	442	19	1	107.90	6.4
	442	21	2	162.97	9.7
	442	41	4	892.34	53.0
	442	42	3	164.18	9.8
	442	54	2	20.85	1.2
* AREA OF ABOVE SUBDIVISION 442		IS 1683.35			
VA. BEACH	444	53	1	15.10	0.6
	444	11	7	460.52	16.9
	444	12	1	23.00	0.8
	444	16	2	55.77	2.0
	444	17	2	55.50	2.0
	444	18	1	27.99	1.0
	444	19	4	155.19	5.7

LAND MANAGEMENT INFORMATION SYSTEMS ENVIRONMENT CANADA DATA SOURCE: U.S. GEOLOGICAL SURVEY

DATE: SEPT.18/73 PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION REF:3190-0002

SCALE 1:50,000

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	444	21	5	692.90	25.4
	444	41	8	914.10	33.5
	444	53	1	37.50	1.4
	444	54	2	287.76	10.6
* AREA OF ABOVE SUBDIVISION 444 IS 2725.46					
VA. BEACH	446	11	14	944.09	31.8
	446	12	8	58.94	2.0
	446	16	1	25.55	0.9
	446	17	1	7.49	0.3
	446	19	3	256.97	8.7
	446	21	4	423.94	14.3
	446	41	4	267.75	9.0
	446	54	2	986.05	33.2
* AREA OF ABOVE SUBDIVISION 446 IS 2970.70					
VA. BEACH	448	11	7	798.71	29.9
	448	12	5	168.51	6.3
	448	15	2	99.71	3.7
	448	16	3	65.12	2.4
	448	18	1	37.57	1.4
	448	19	3	310.39	11.6
	448	21	6	730.46	27.4
	448	41	6	449.90	16.9
	448	42	2	1.08	0.0
	448	54	3	8.09	0.3
* AREA OF ABOVE SUBDIVISION 448 IS 2669.42					

DATE: SEPT.18/73
SCALE 1:50,000

REF:3190-0002
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PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
VA. BEACH	450	11	4	47.10	0.9
	450	14	1	71.05	1.4
	450	15	1	1752.60	34.4
	450	16	2	1087.13	21.3
	450	17	5	14.99	0.3
	450	19	6	327.59	6.4
	450	21	9	1201.67	23.6
	450	41	9	540.88	10.6
	450	42	3	59.27	1.2
* AREA OF ABOVE SUBDIVISION 450		IS 5102.52			
VA. BEACH	452	16	3	430.30	17.5
	452	19	2	438.27	17.8
	452	21	1	22.95	0.9
	452	41	2	977.29	39.8
	452	42	4	382.67	15.6
	452	52	4	48.29	2.0
	452	54	42	25.45	1.0
	452	74	2	131.67	5.4
* AREA OF ABOVE SUBDIVISION 452		IS 2456.88			
VA. BEACH	454	11	6	597.31	1.7
	454	12	1	41.08	0.1
	454	15	1	108.00	0.3
	454	16	5	75.71	0.2
	454	17	3	136.20	0.4

DATE: SEPT.18/73
SCALE 1:50,000

P R E S E N T L A N D U S E B Y C E N S U S D I V I S I O N
A N D S U B D I V I S I O N

REF: 3190-0002
PAGE 48

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA	CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	454		19	6	827.51	2.3
	454		21	19	15779.24	44.3
	454		41	39	14460.10	40.6
	454		42	9	902.12	2.5
	454		51	17	67.14	0.2
	454		52	3	357.02	1.0
	454		53	2	45.56	0.1
	454		54	24	652.88	1.8
	454		61	4	1260.37	3.5
	454		74	1	338.81	1.0
* AREA OF ABOVE SUBDIVISION 454		IS	35646.68			
VA. BEACH	456		11	4	718.51	50.2
	456		12	4	48.03	3.4
	456		14	1	9.92	0.7
	456		15	1	15.86	1.1
	456		19	1	59.91	4.2
	456		21	2	0.94	0.1
	456		41	3	481.58	33.7
	456		54	3	95.30	6.7
* AREA OF ABOVE SUBDIVISION 456		IS	1430.05			
VA. BEACH	458		11	2	712.59	26.3
	458		12	1	20.24	0.7
	458		14	1	86.37	3.2
	458		15	1	8.97	0.3

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LAND MANAGEMENT INFORMATION SYSTEMS ENVIRONMENT CANADA DATA SOURCE: U.S. GEOLOGICAL SURVEY

DATE: SEPT,16/73
SCALE 1:250,000

PRESENT LAND USE BY CENSUS DIVISION
AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	458	16	1	38.19	1.4
	458	19	6	279.35	10.3
	458	21	2	943.30	34.9
	458	41	9	565.81	20.9
	458	53	1	51.76	1.9
* AREA OF ABOVE SUBDIVISION 458		IS 2706.63			
VA. BEACH	460	11	11	1864.00	24.4
	460	12	1	106.06	1.4
	460	15	3	60.99	0.8
	460	16	7	238.26	3.1
	460	17	2	91.11	1.2
	460	19	5	223.44	2.9
	460	21	10	3085.50	40.4
	460	41	20	1680.78	22.0
	460	53	4	77.53	1.0
	460	54	1	27.19	0.4
	460	61	1	184.90	2.4
* AREA OF ABOVE SUBDIVISION 460		IS 7639.75			
VA. BEACH	462	11	12	1488.24	12.9
	462	12	2	222.92	1.9
	462	13	1	20.85	0.2
	462	15	1	55.01	0.5
	462	16	2	49.07	0.4
	462	17	4	156.44	1.4

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CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. DATA CLASS	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	462	19	6	456.11	4.0
	462	21	9	4969.27	43.2
	462	41	13	3281.18	28.5
	462	42	4	286.09	2.5
	462	52	1	70.52	0.6
	462	53	4	133.42	1.2
	462	54	1	153.71	1.3
	462	61	2	151.46	1.3
* AREA OF ABOVE SUBDIVISION 462 IS 11495.99					
VA. BEACH					
	464	11	1	20.82	0.0
	464	15	1	120.19	0.2
	464	19	5	167.13	0.3
	464	21	9	14604.47	23.1
	464	41	50	9964.95	15.8
	464	42	5	165.13	0.3
	464	51	28	1346.18	2.1
	464	54	80	24422.02	38.7
	464	61	32	9901.40	15.7
	464	72	3	83.12	0.1
	464	74	1	2348.76	3.7
* AREA OF ABOVE SUBDIVISION 464 IS 63144.00					
VA. BEACH	465	51	1	77.93	0.4
	466	16	1	16.11	0.1

PRESENT LAND USE BY CENSUS DIVISION AND SUBDIVISION

CENSUS DIVISION	CENSUS SUBDIVISION	P.L.U. CLASS DATA	NO. OF OCCUR. PLU IN SUBDIV.	AREA (ACRES)	% P.L.U. OF SUBDIV. AREA
	466	21	10	642[illegible].5[illegible]	29.5
	466	41	8	10[illegible]	49.0
	466	42	2	5[illegible].4[illegible]	0.3
	466	51	1	1102.61	5.1
	466	61	21	3425.87	15.7

* AREA OF ABOVE SUBDIVISION 466 IS 21752.29

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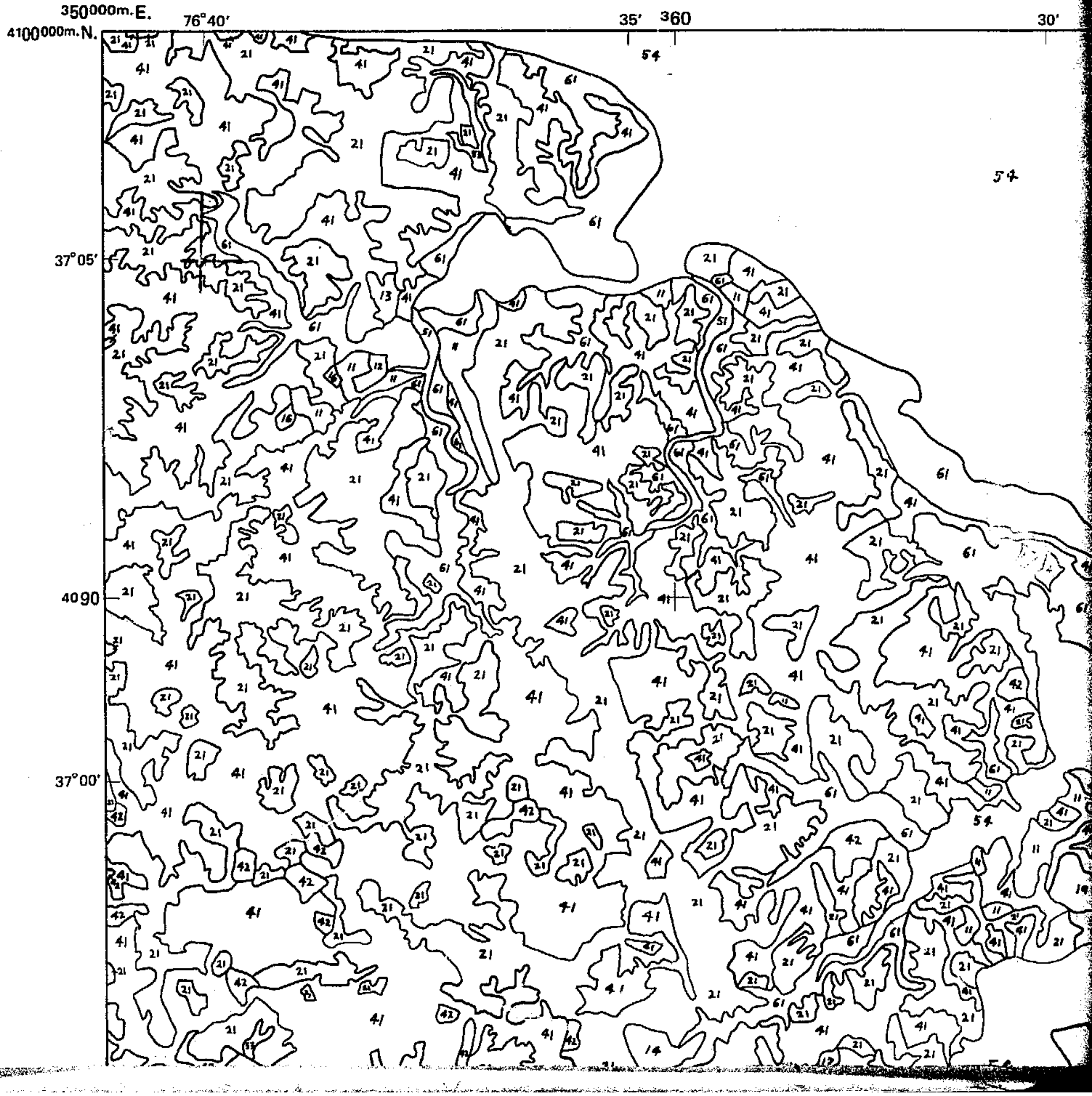
(CHARLES CITY)

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

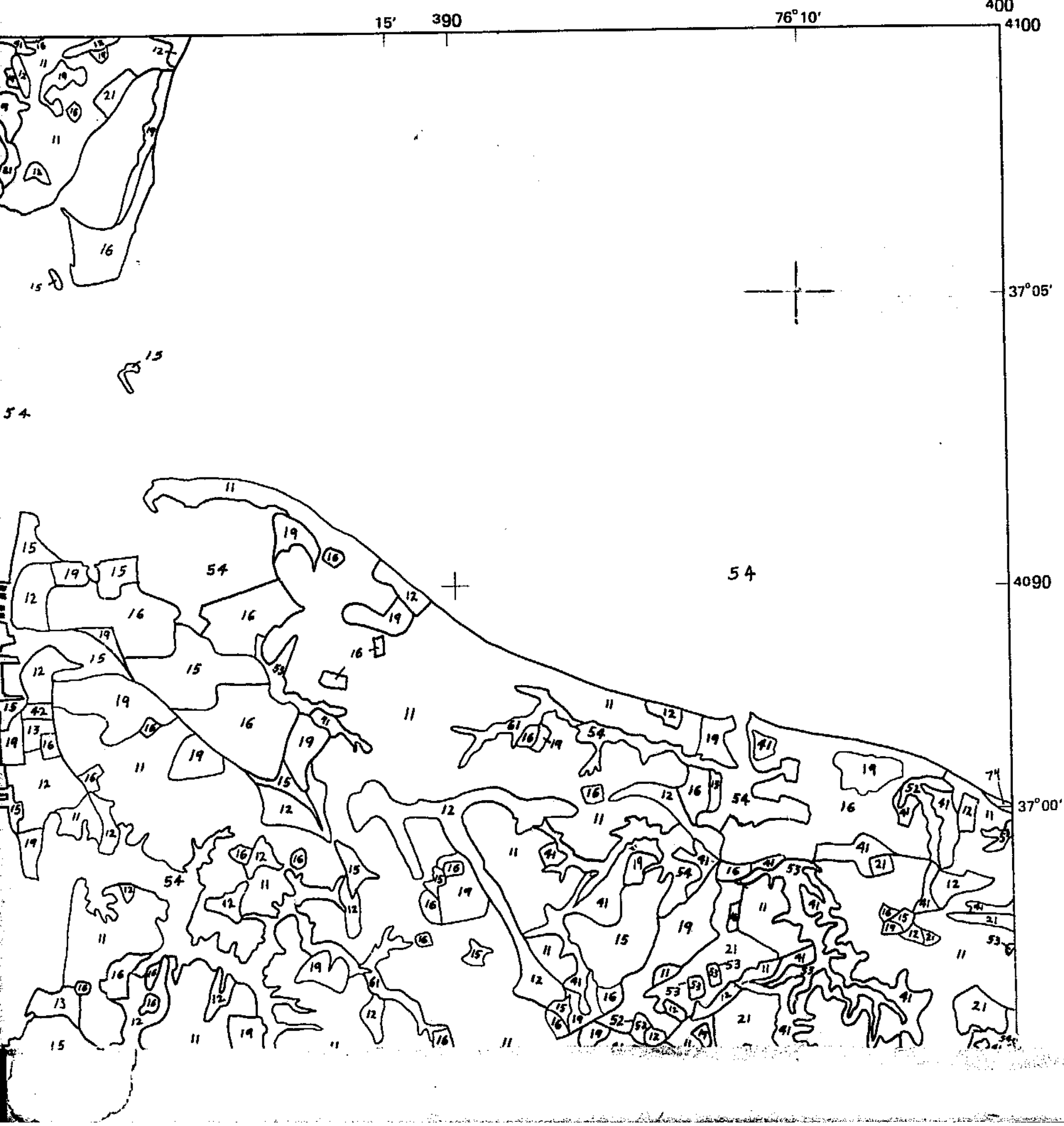


FOLDOUT FRAME 2

Plate 1.

FOLDOUT FRAME 3

OPEN FILE MAP
CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE
NORFOLK SHEET, VA.–LAND USE, 1970



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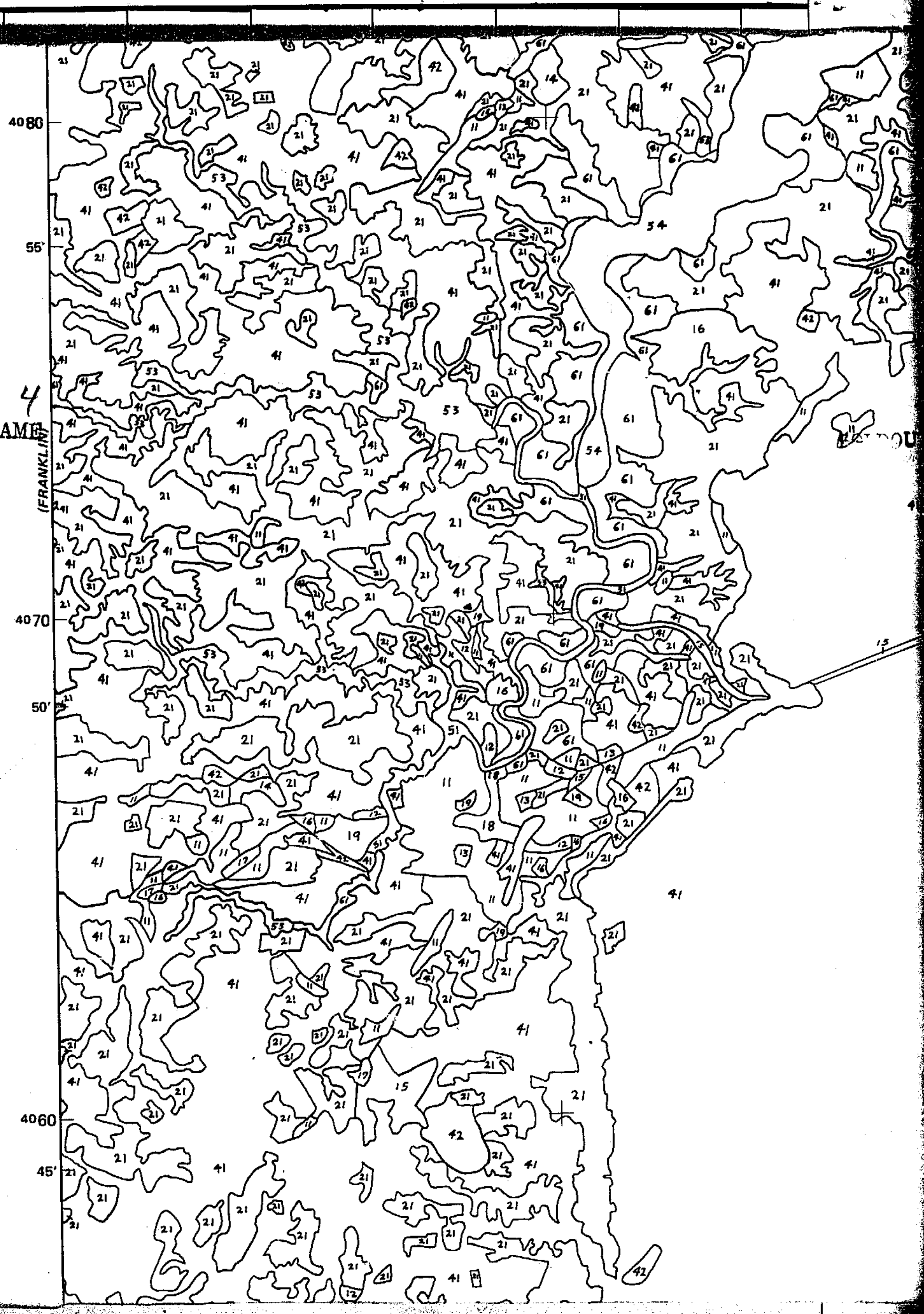


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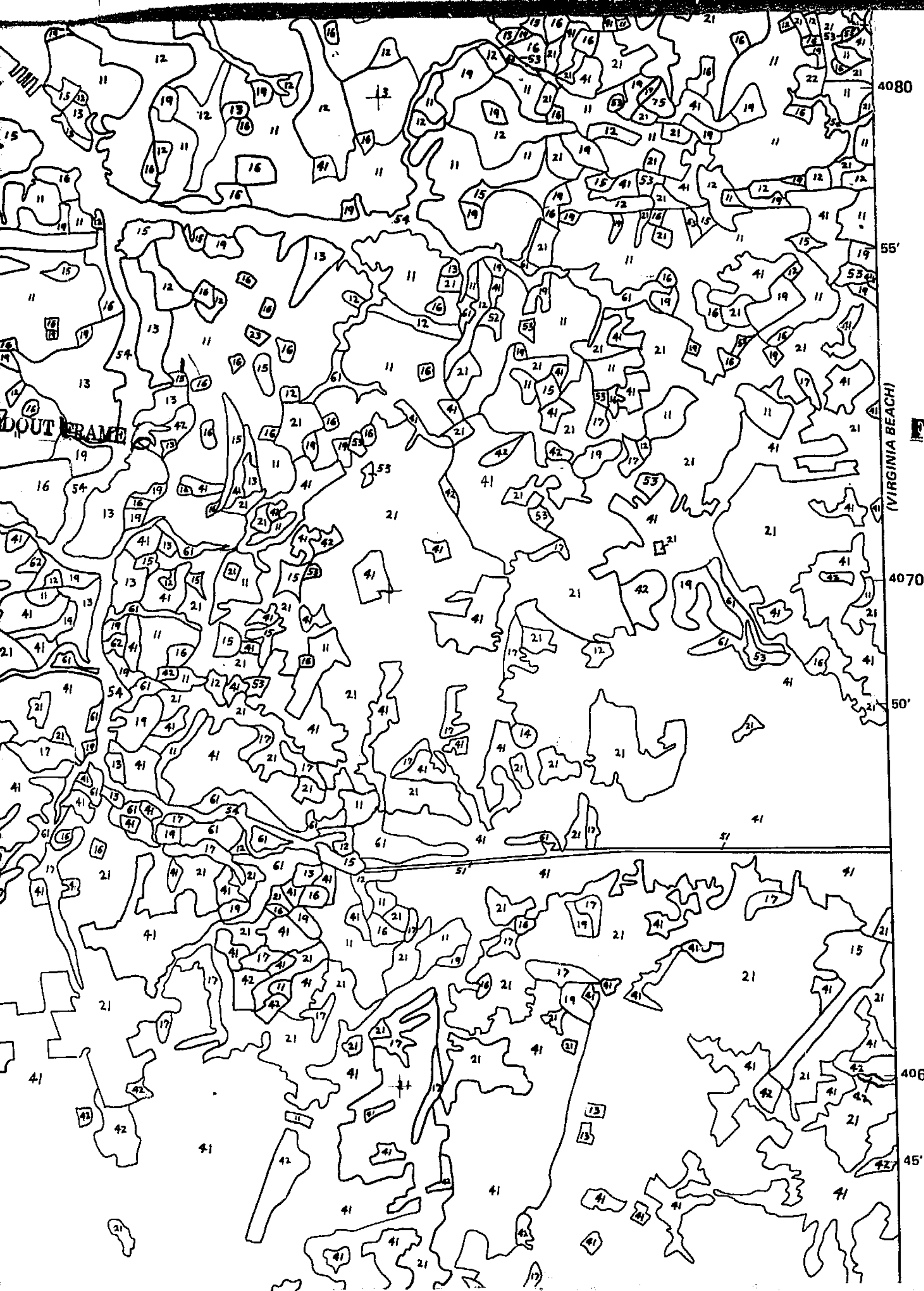

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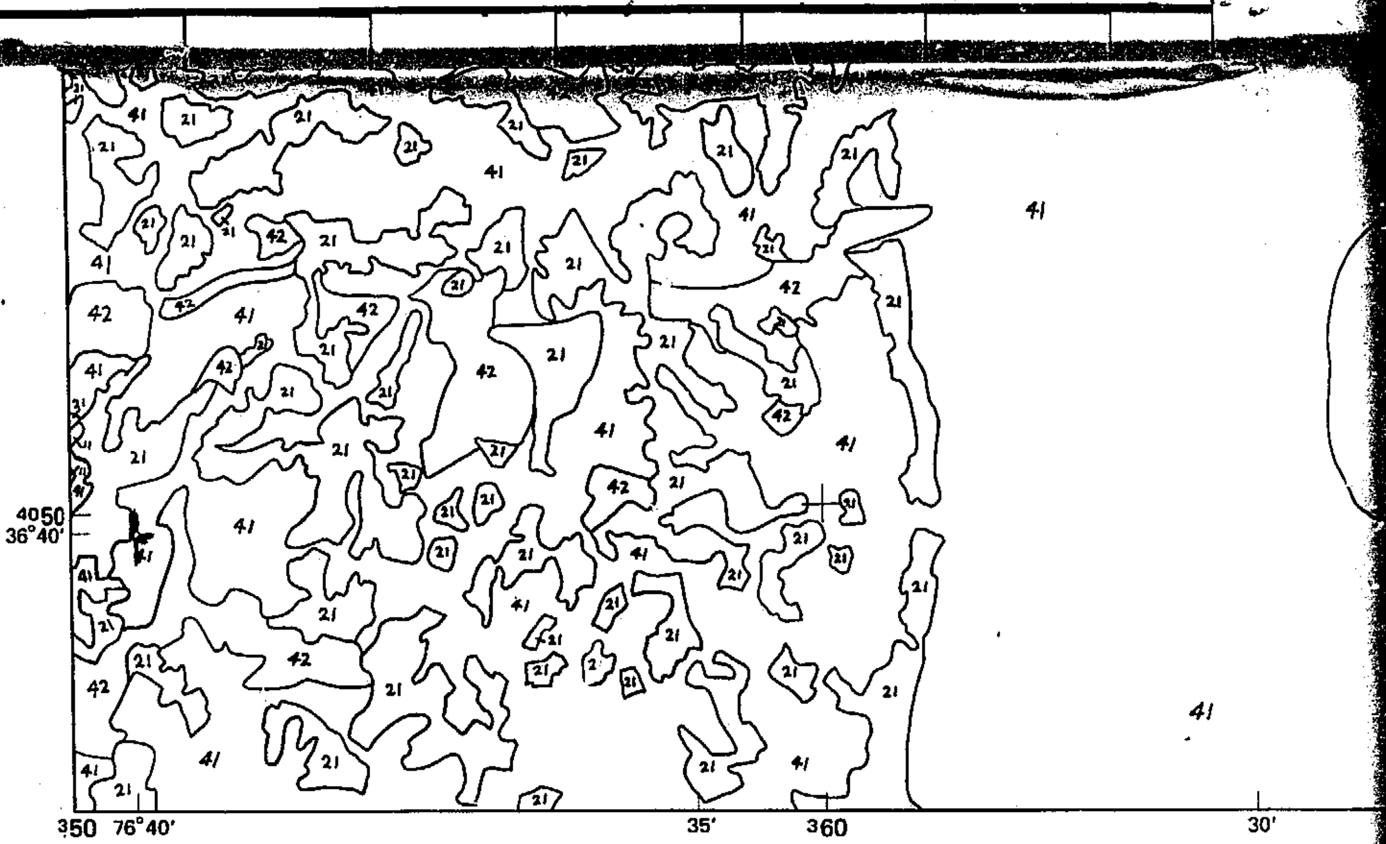


Land-use data compiled by the U.S. Geological Survey from 1:120,000-scale aerial photographs acquired by the National Aeronautics and Space Administration, Earth Resources Program, Aircraft Mission 144, September 1970

5-minute geographic projection ticks and 10,000 meter ticks: Universal Transverse Mercator, zone 18, 1927 North American datum

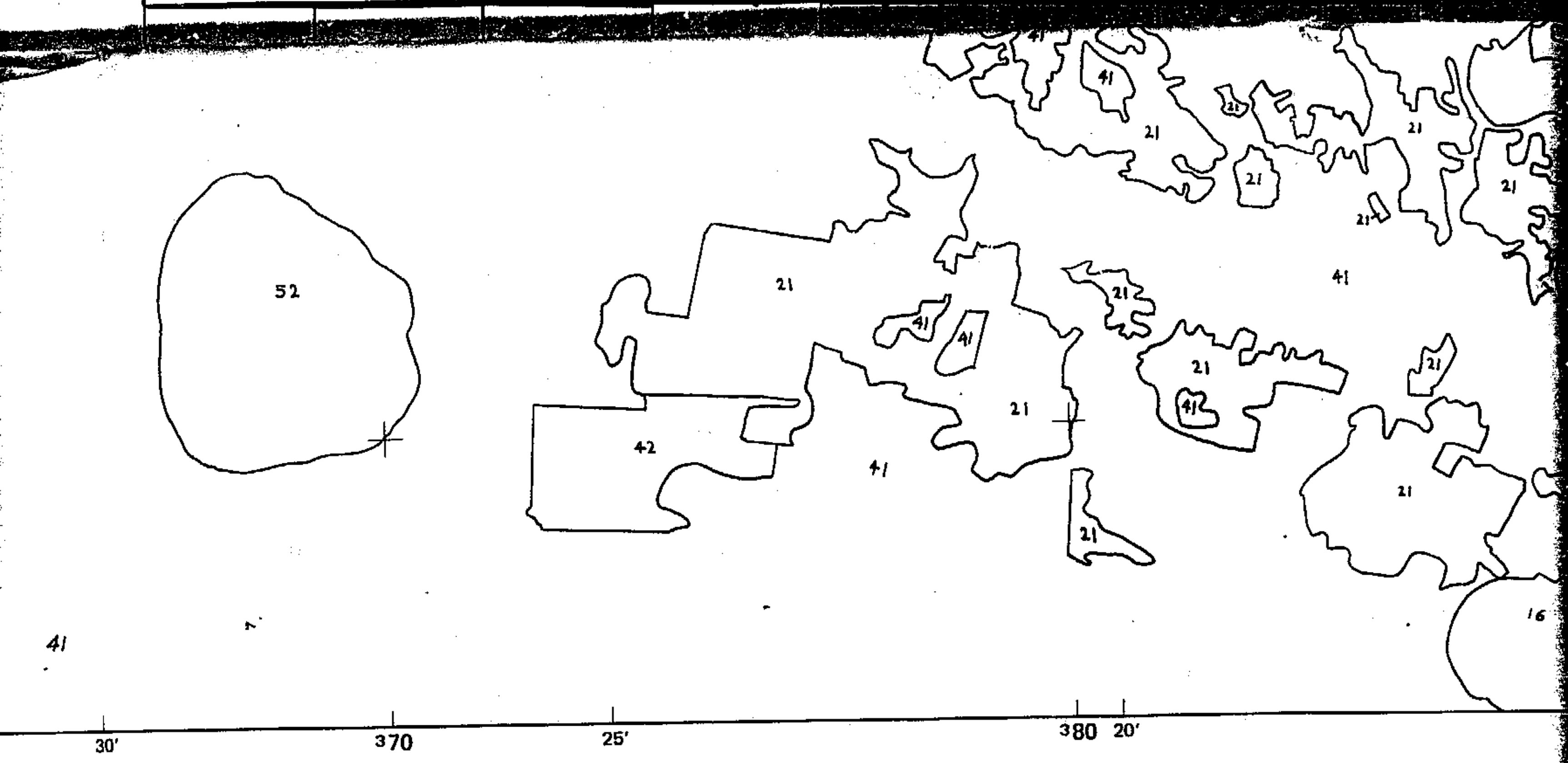
Land-use classification categories are in general conformance with those proposed by the Inter-Agency Steering Committee on Land Use Information and Classification in U.S. Geological Survey Circular 671 (1972). This compilation is not edited or field checked

LAND USE CLASSIFICATION LEGEND

URBAN AND BUILTUP	Residential	11
	Commercial and services	12
	Industrial	13
	Extractive	14
	Transportation, communications, and utilities	15
	Institutional	16
	Strip and clustered settlement	17
	Mixed	18
	Open and other	19
AGRICULTURAL	Cropland and pasture	21
	Orchards, groves, bush fruits, vineyards, and horticultural areas	22
	Feeding operations	23
	Other	24
FORESTLAND	Heavy Crown Cover (40% and over)	41
	Light Crown Cover (10% to 30%)	42
WATER	Streams and waterways	51
	Lakes	52
	Reservoirs	53
	Bays and estuaries	54
	Other	55
NON-FORESTED WETLAND	Vegetated	61
	Bare	62
BARREN LAND	Sand other than beaches	72
	Bare exposed rock	73
	Beaches	74
	Other	75

LAND USE

FOLDOUT FRAME 8



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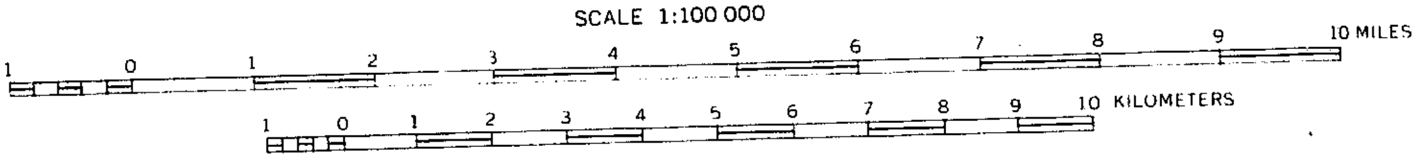

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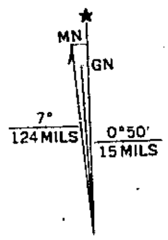


UTM GRID AND 1973 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

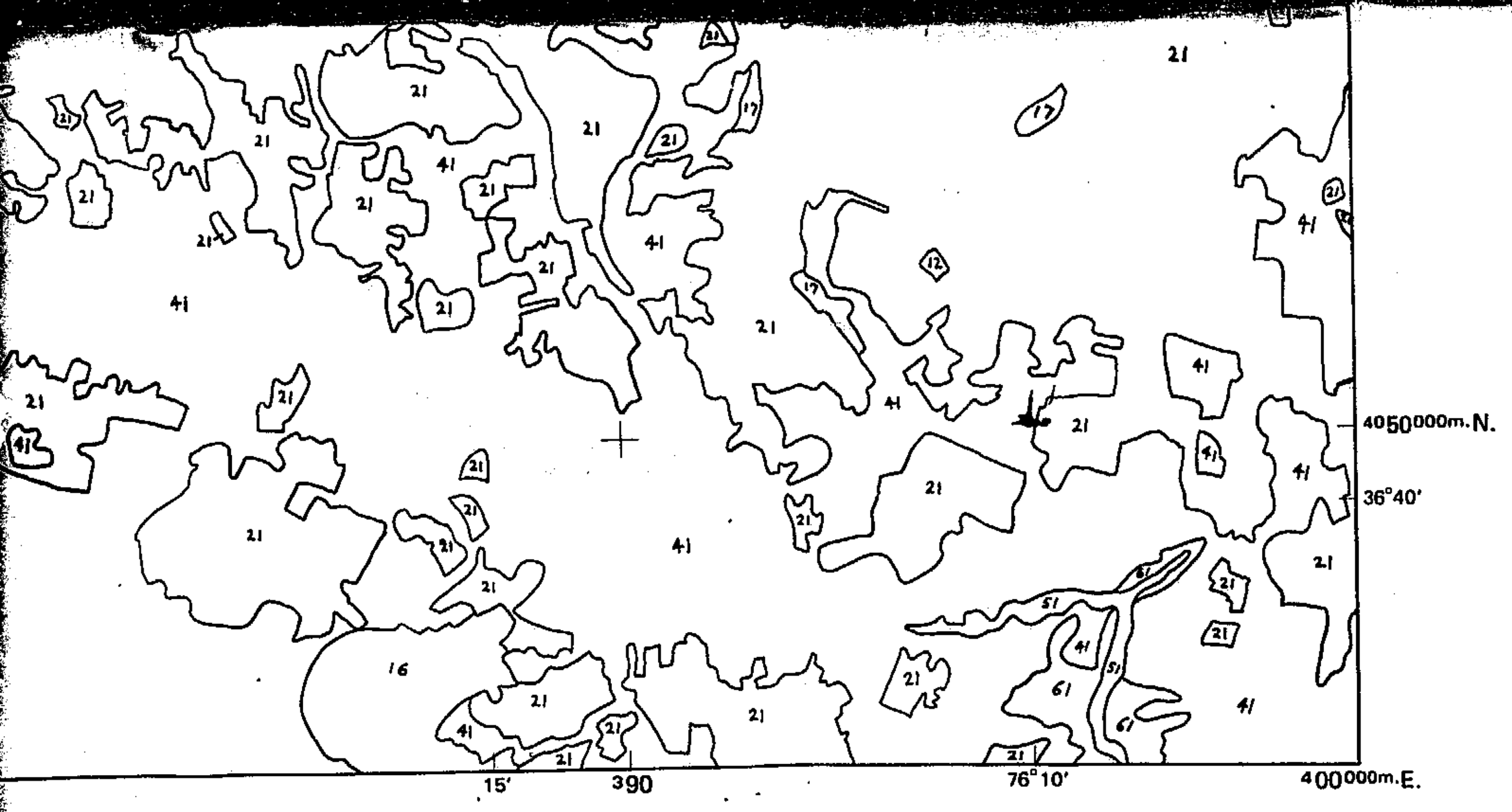
EXPERIMENTAL EDITION

Comments, corrections, or suggestions may be submitted to the Geographic Applications Program, U.S. Geological Survey Washington, D.C. 20244

ND USE MAP IN 1970 OF THE NORFOLK SHEET, V

1973

FOLDOUT FRAME 9



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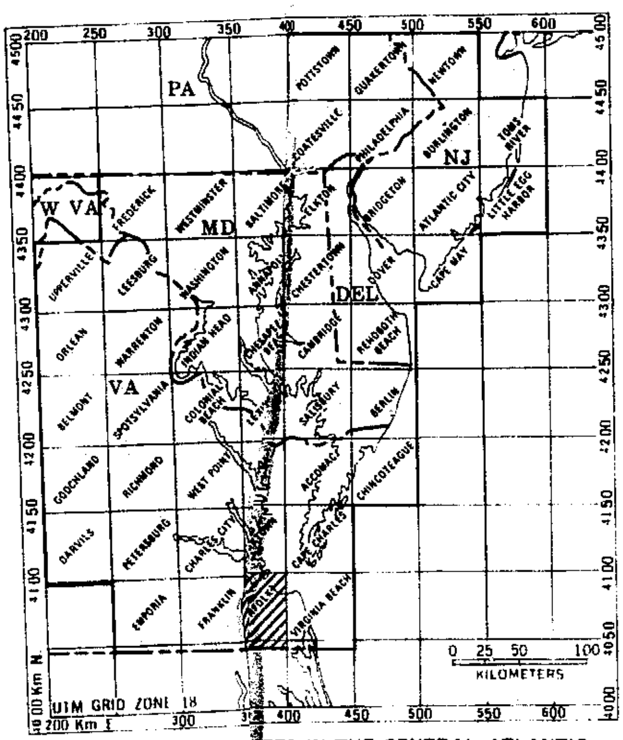
LOCATION DIAGRAM



INDEX TO MOSAIC SETS IN THE CENTRAL ATLANTIC
REGIONAL ECOLOGICAL TEST SITE

47

LK SHEET, VA.

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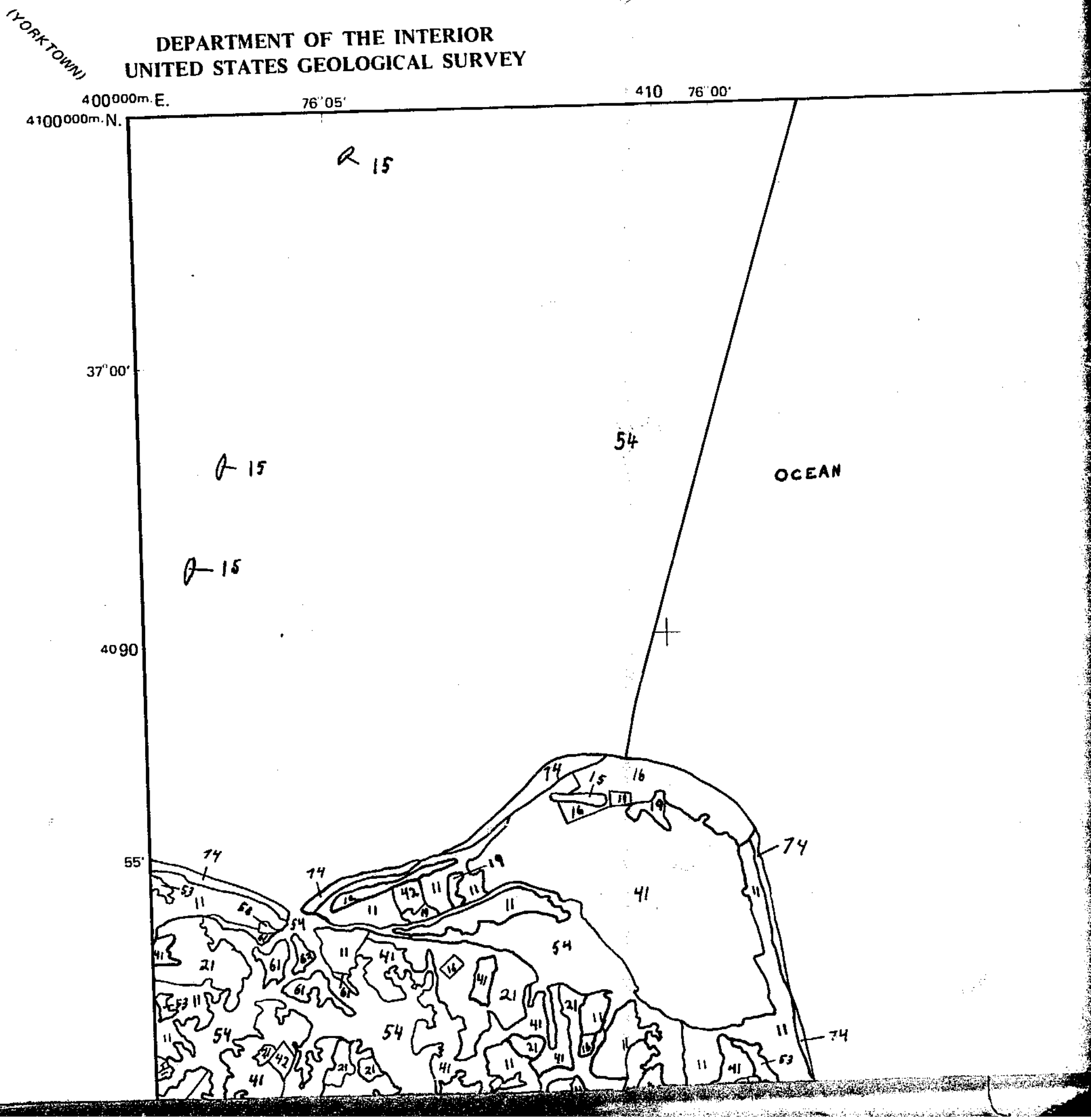
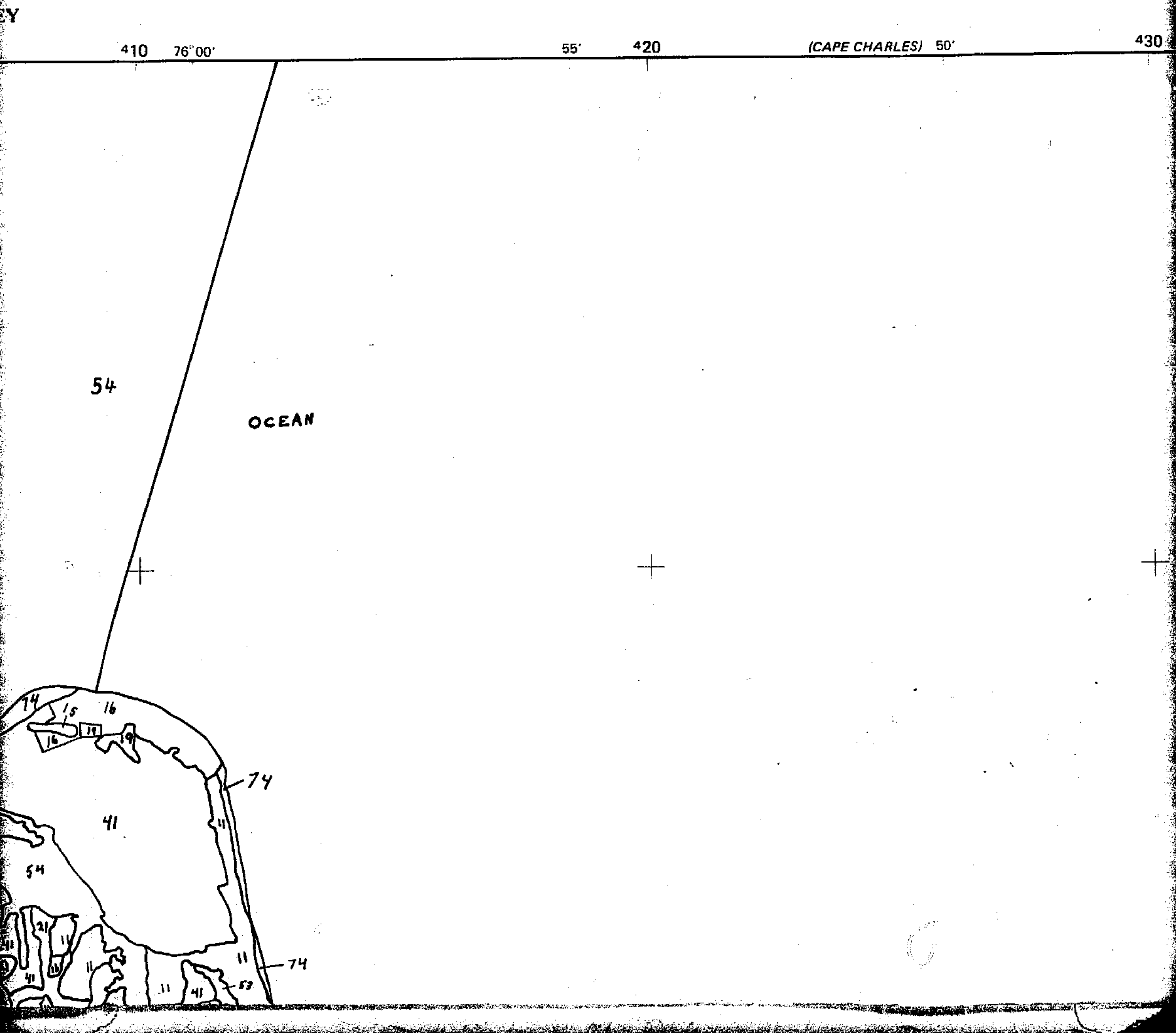
FOLDOUT FRAME

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY



FOLDOUT FRAME 2

Plate 2



FOLDOUT FRAME 3

OPEN FILE MAP
CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE
VIRGINIA BEACH SHEET, VA.–LAND USE, 1970

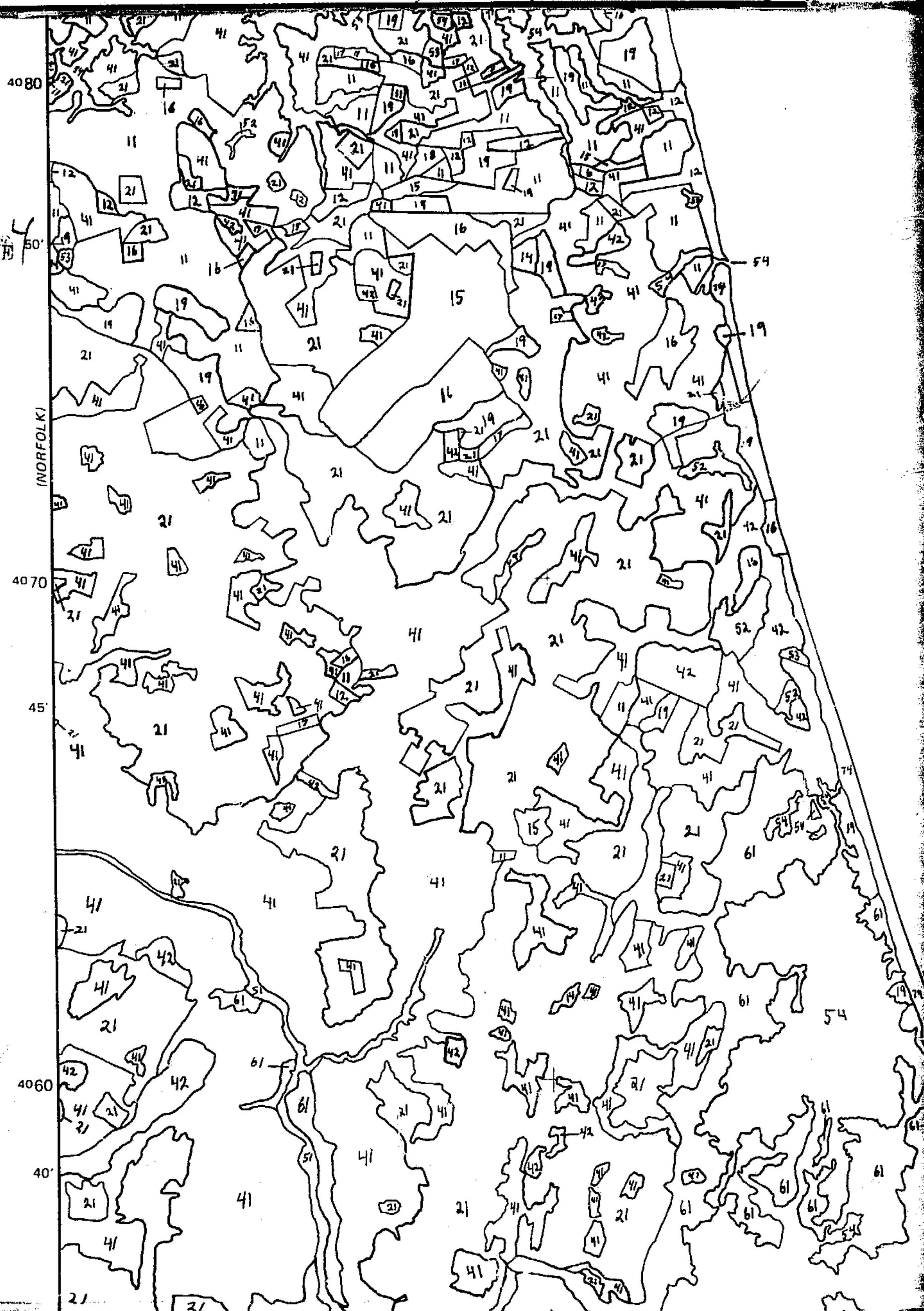
45′ 440 40′ 75°35′ 450 4100

37°00′

4090

55′

FOLDOUT FRAME 4



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45'

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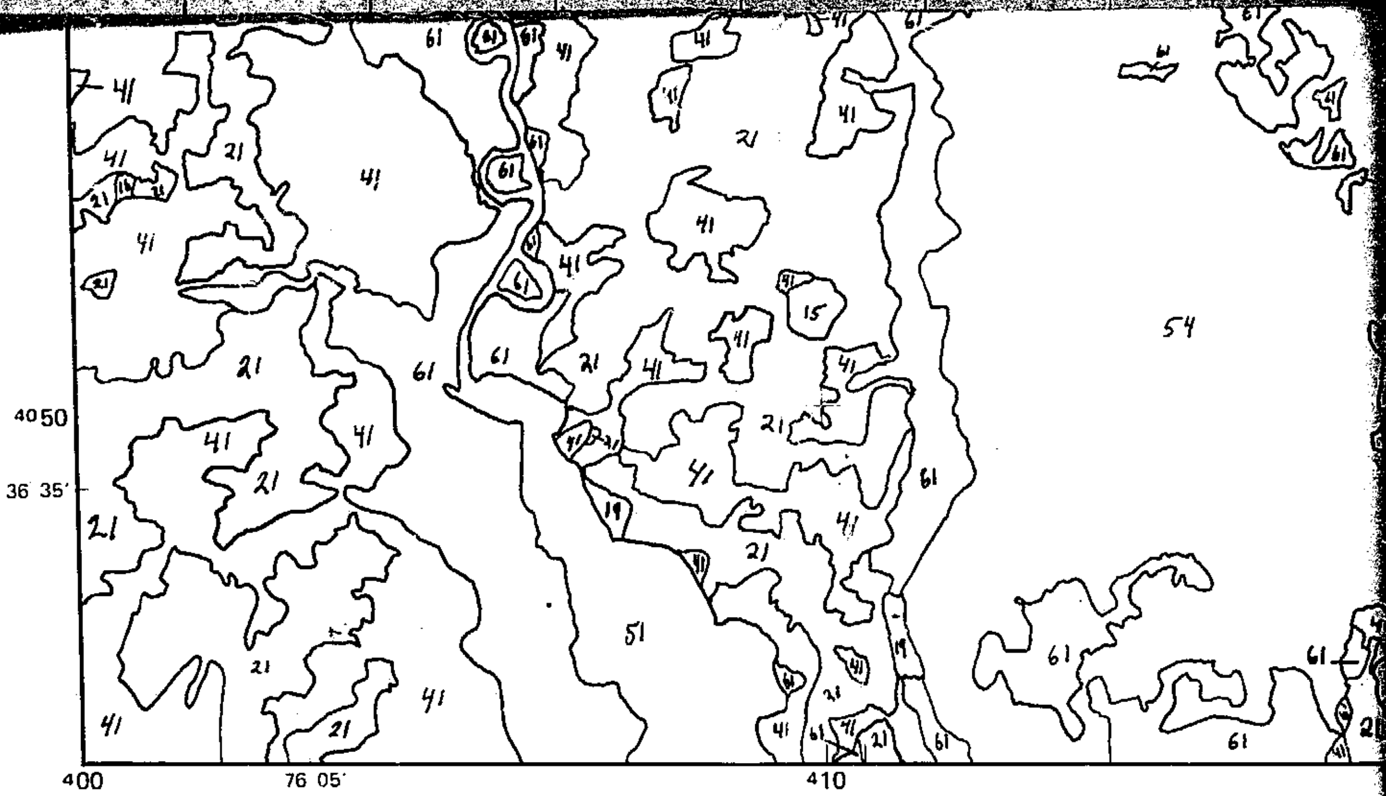
40'



Land-use data compiled by the U.S. Geological Survey from 1:120,000-scale aerial photographs acquired by the National Aeronautics and Space Administration, Earth Resources Program, Aircraft Mission 144, September 1970

5-minute geographic projection ticks and 10,000 meter ticks: Universal Transverse Mercator, zone 18, 1927 North American datum

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	Beaches	74
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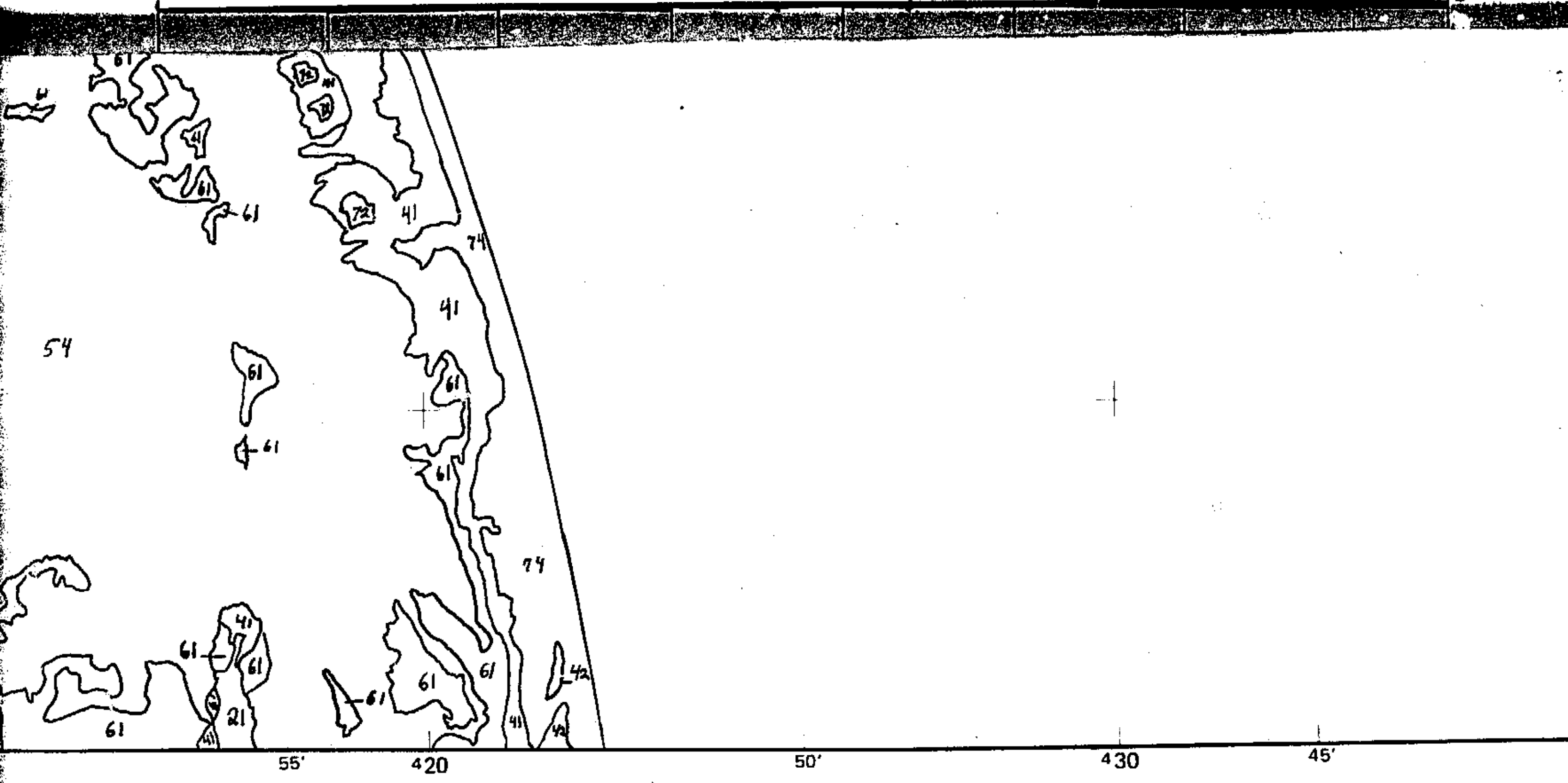
LAND USE MA



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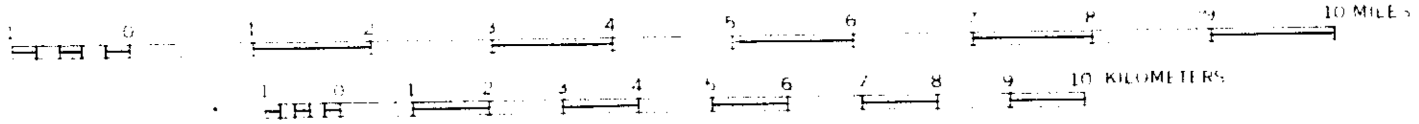

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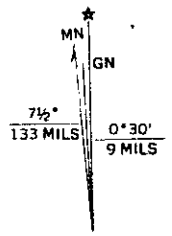


UTM GRID AND 1973 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

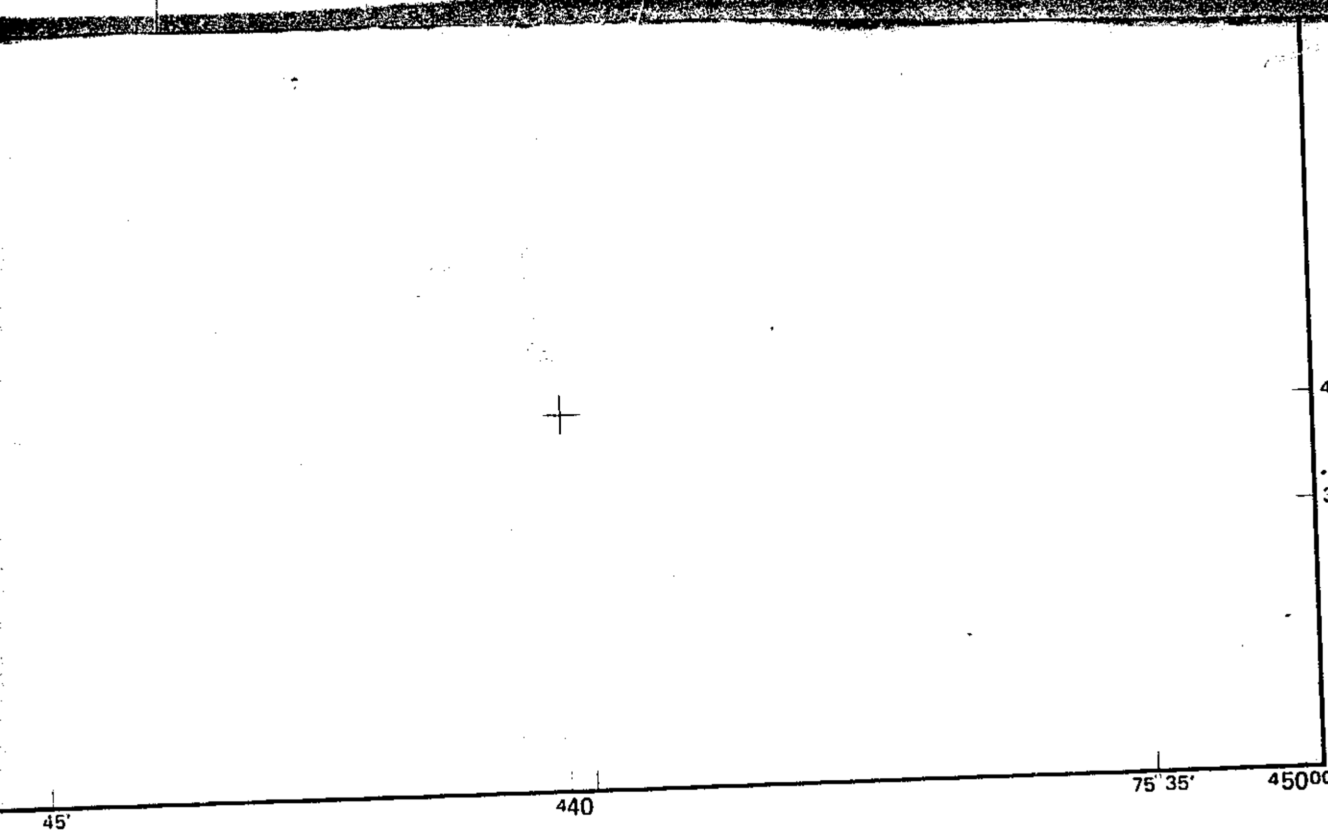
EXPERIMENTAL EDITION

Comments, corrections, or suggestions may be submitted to the Geographic Applications Program, U.S. Geological Survey Washington, D.C. 20244

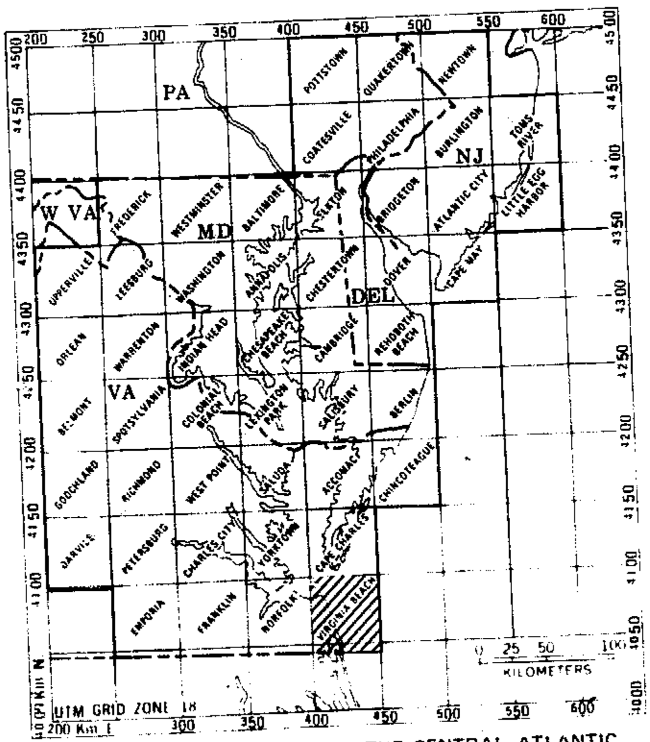
USE MAP IN 1970 OF THE VIRGINIA BEACH SHE

FOLDOUT FRAME 8

1973



LOCATION DIAGRAM



INDEX TO MOSAIC SHEETS IN THE CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE

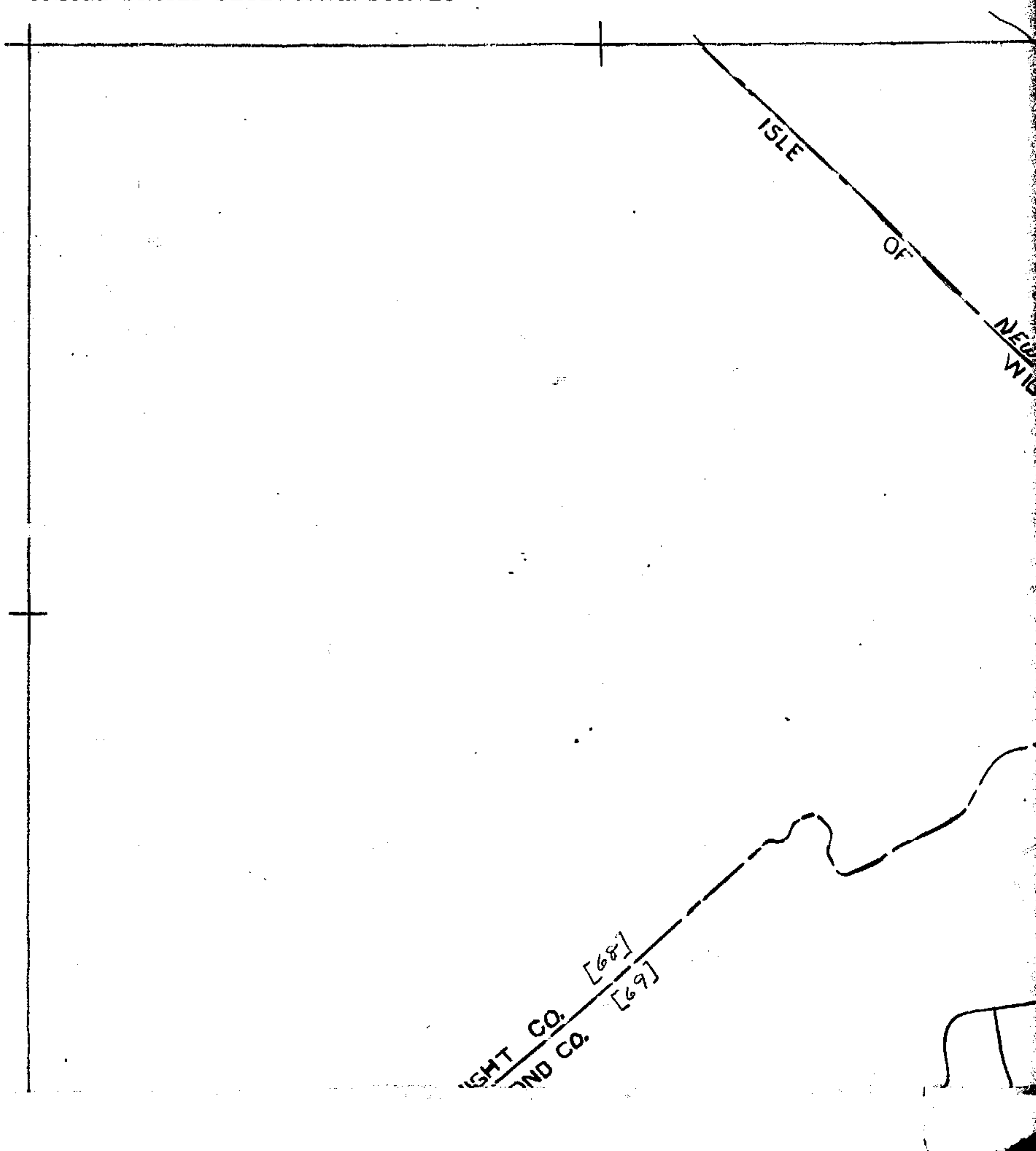
48

EACH SHEET, VA.

FOLDOUT FRAME 9

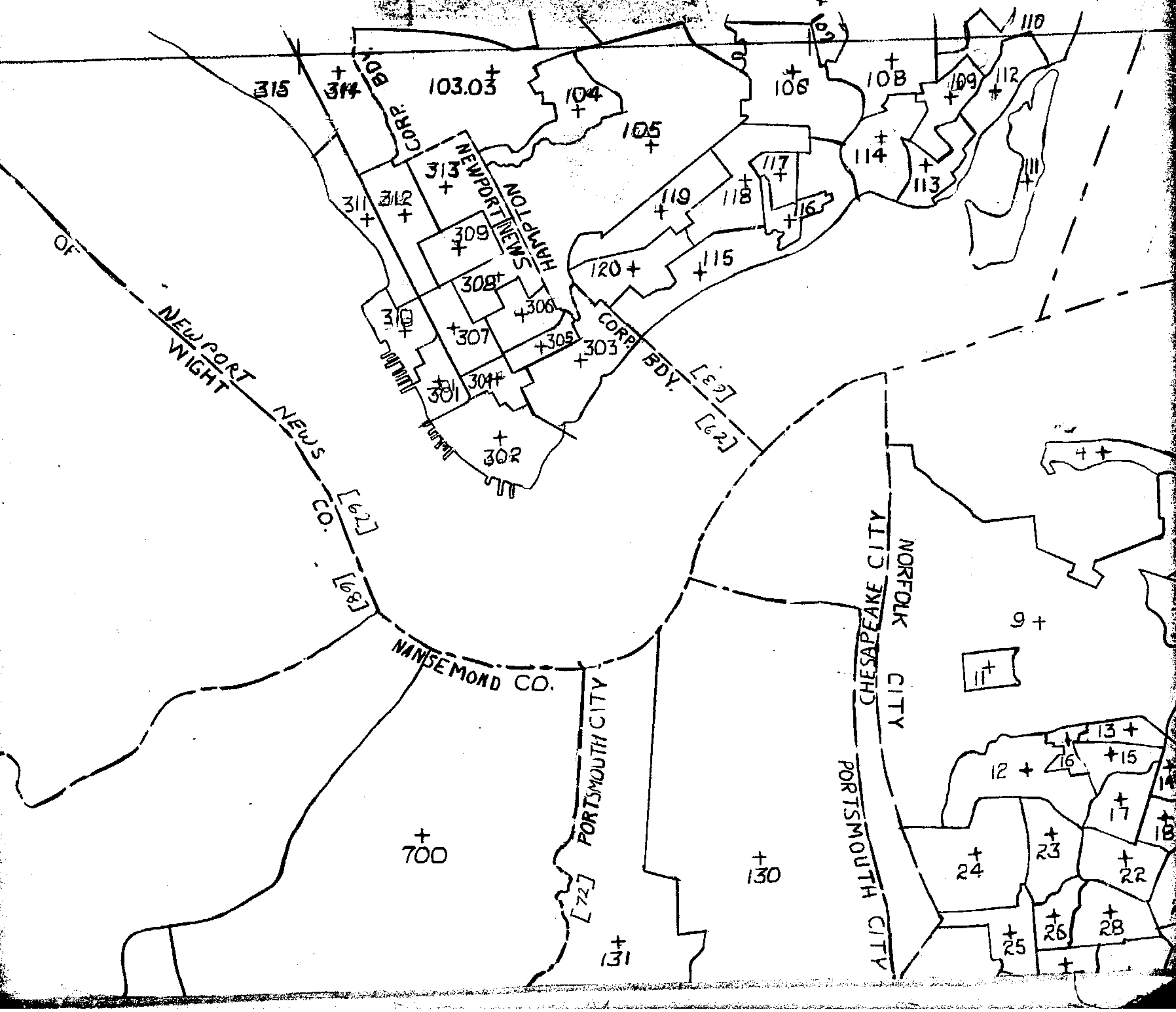
FOLDOUT FRAME 1

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY



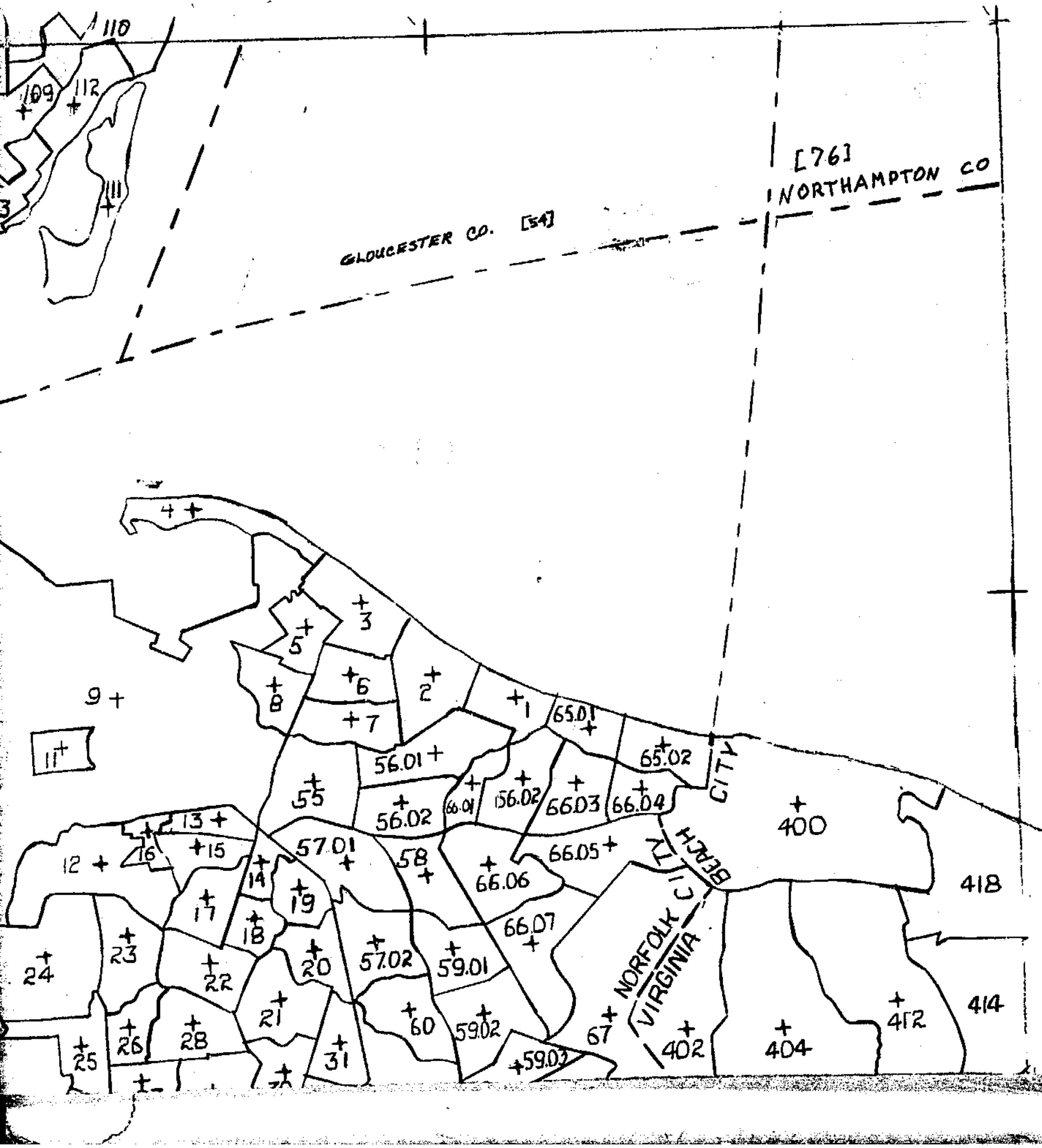
FOLDOUT FRAME 2

Plate 3



FOLDOUT FRAME 3

OPEN FILE MAP—1973



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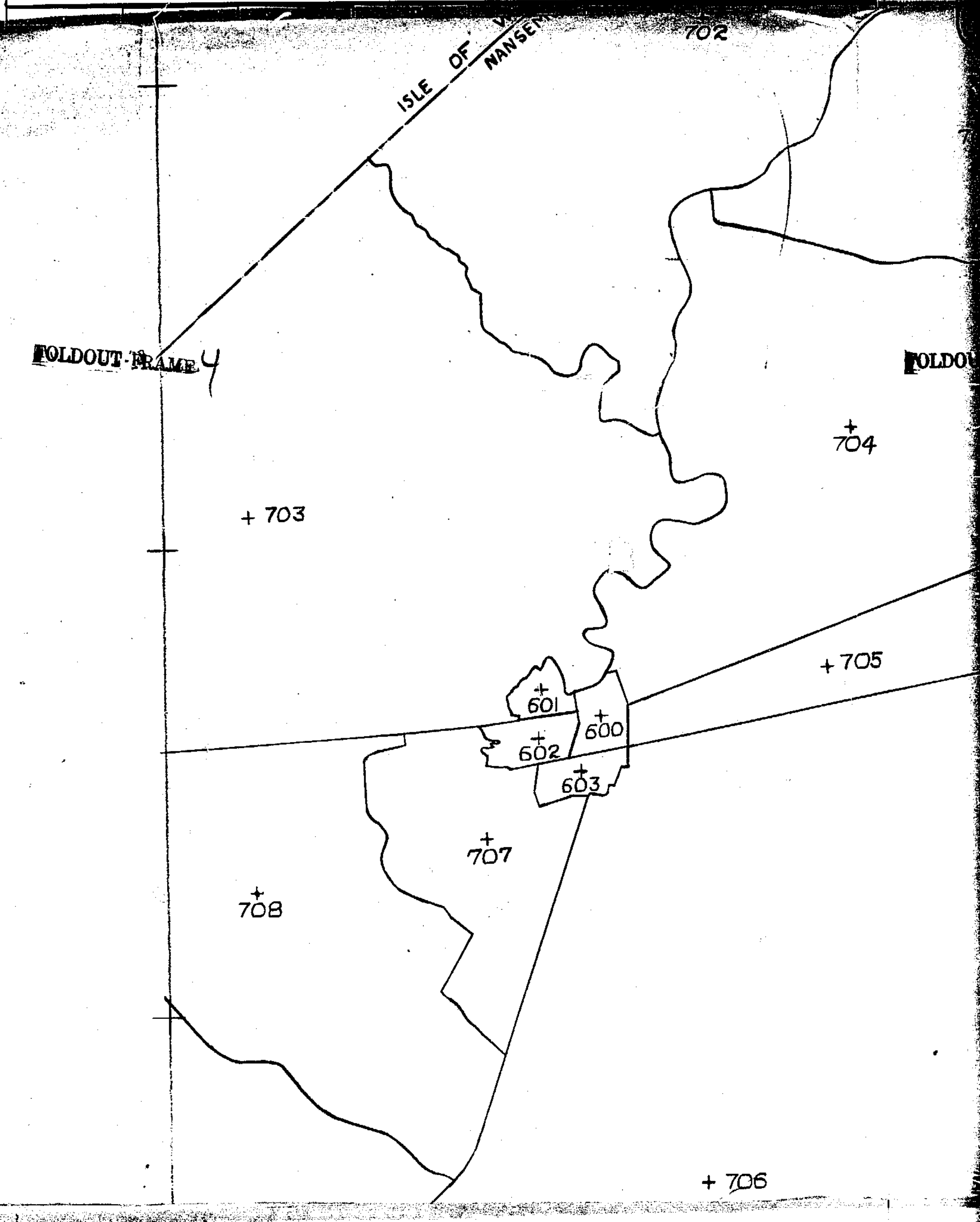

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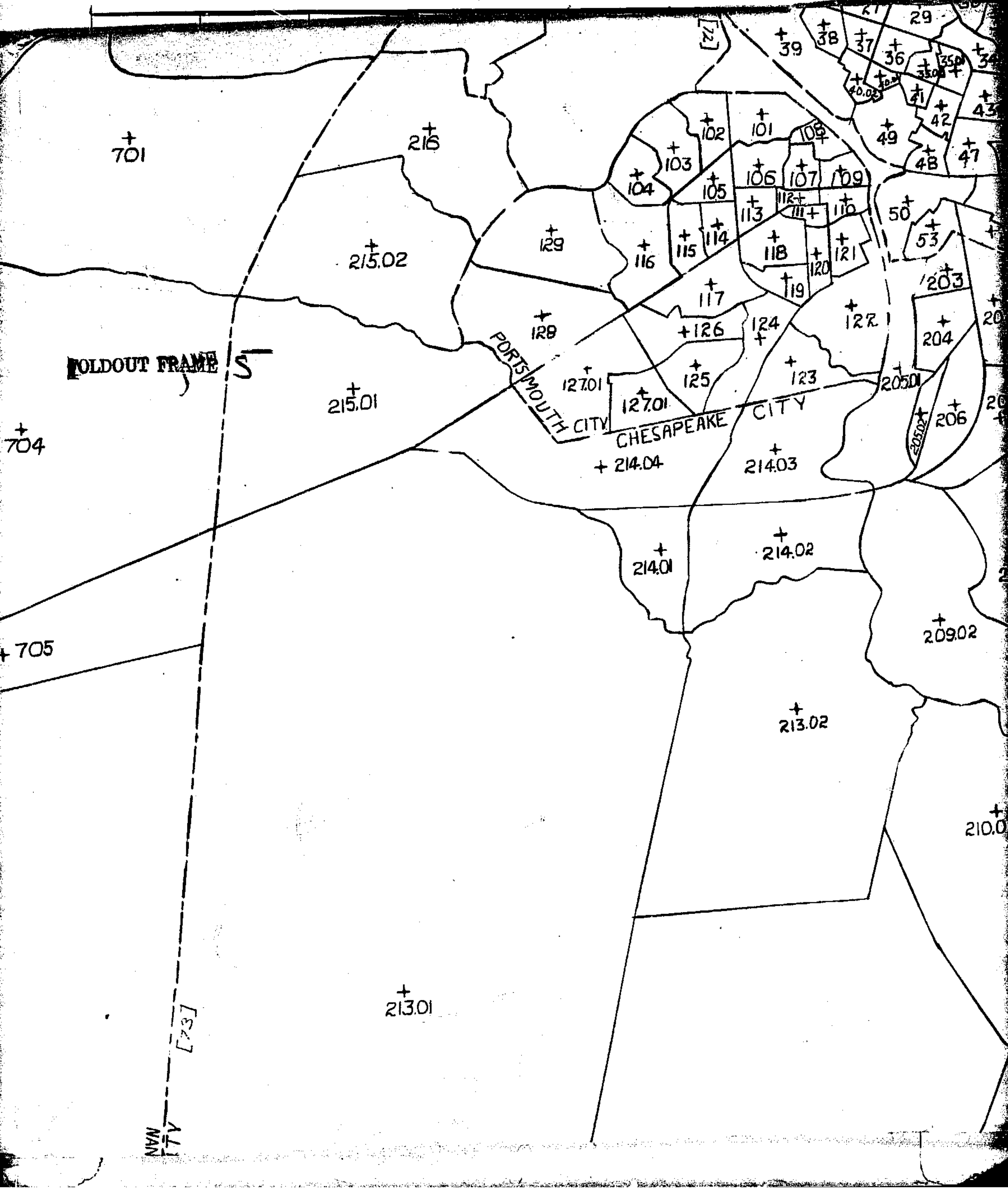

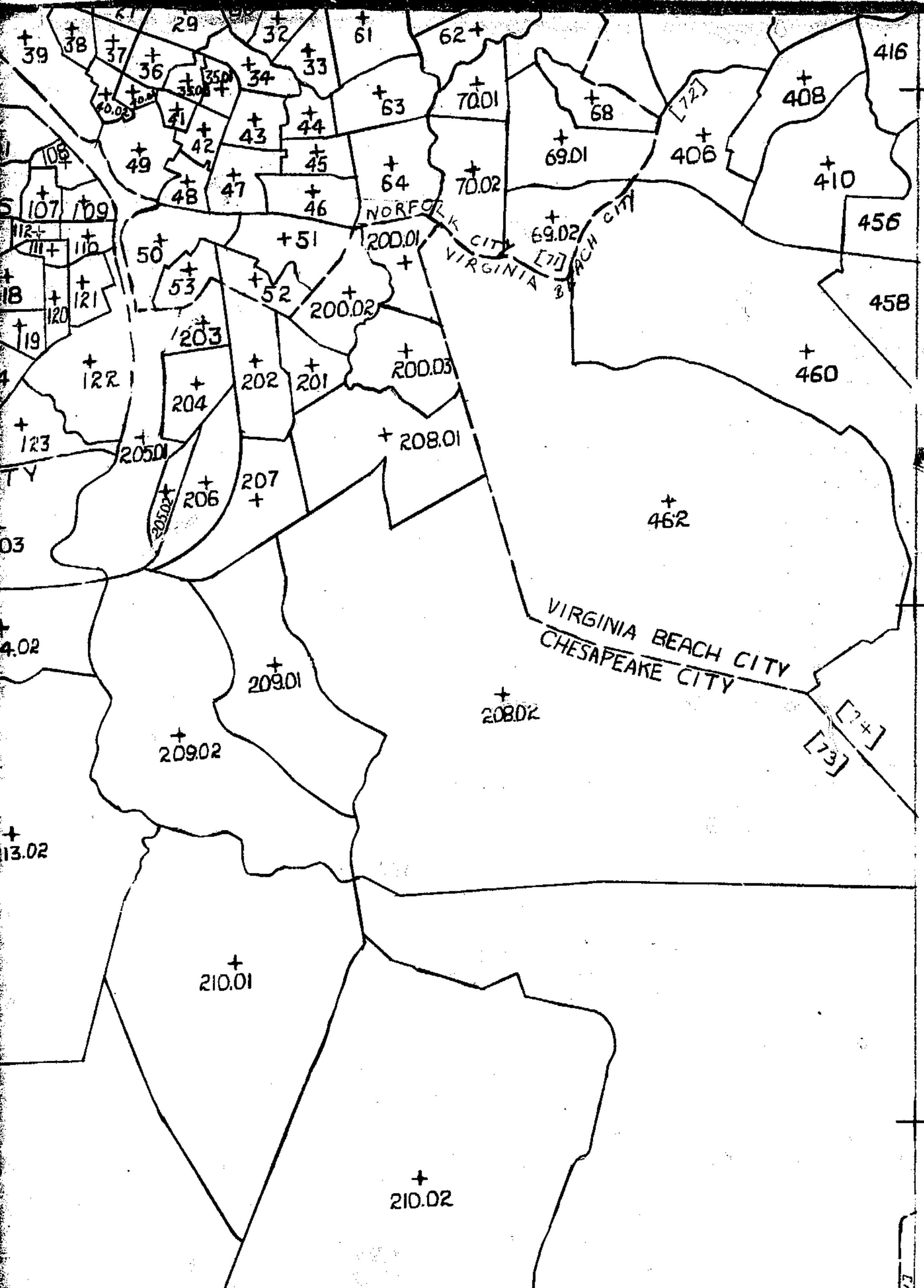

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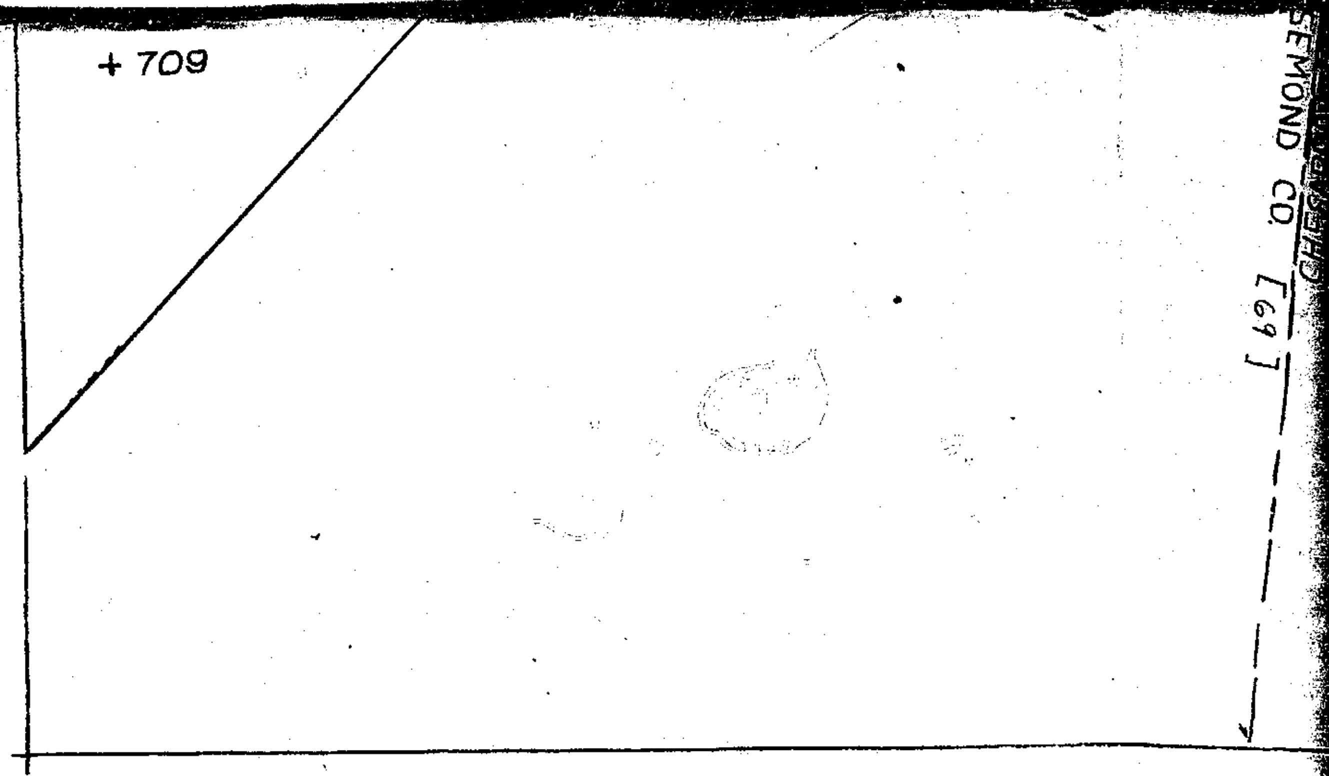

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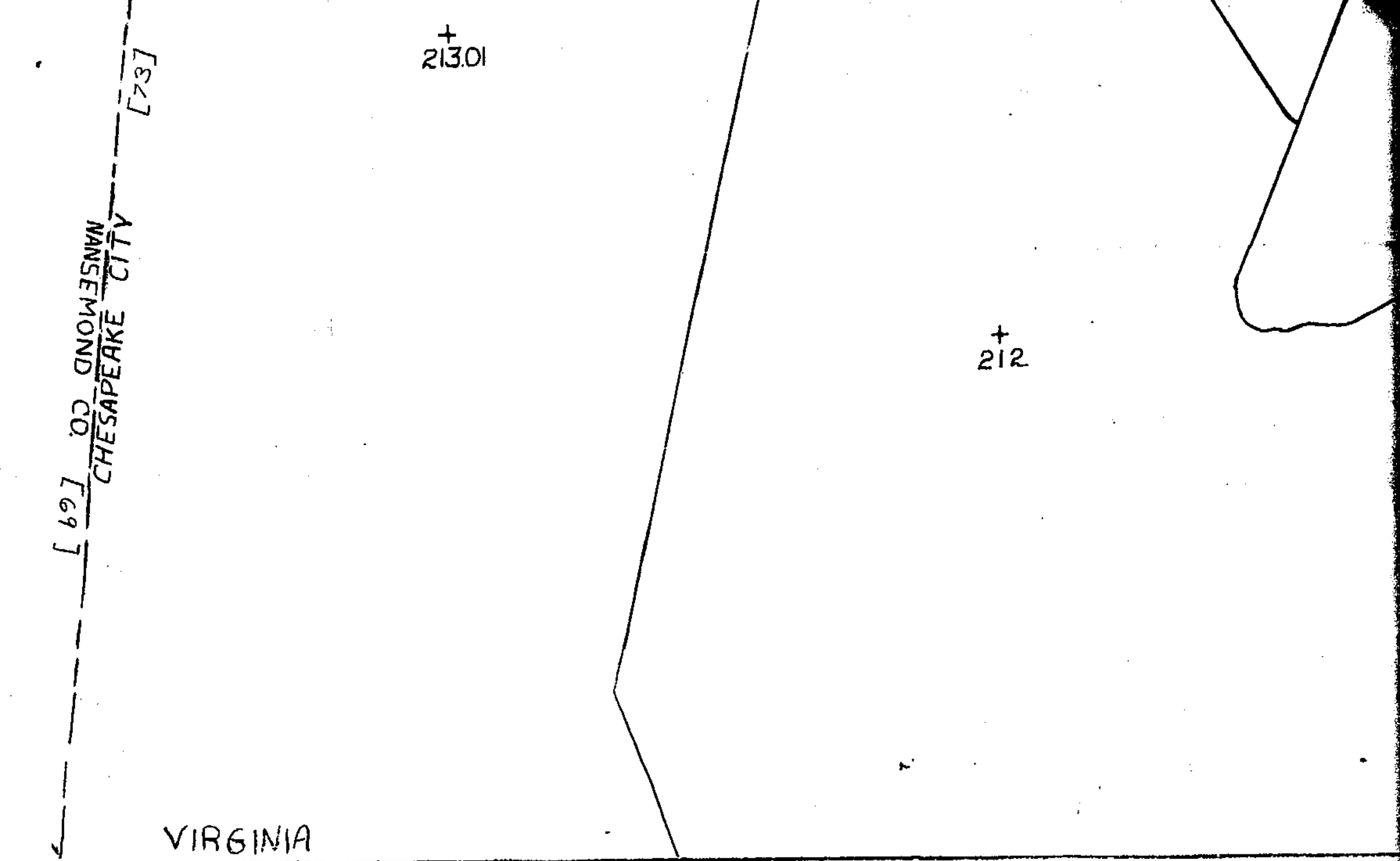

SCALE 1:100 000

This map is keyed to the "Central Atlantic Regional Ecological Test Site Norfolk Sheet, Va. Land Use, 1970, Open File Map—1973" which is gridded with both the UTM and Geographic Coordinate Systems.

County and incorporated city boundaries compiled by the U.S. Geological Survey from U.S.G.S. maps of the 1:250,000 scale Topographic Map Series.

Census tract data compiled by the U.S. Geological Survey from U.S. Department of Commerce "U.S. Census of Population and Housing: 1970".

State boundary	— — — —
County boundary	— — — —
City boundary	— — —
Census tract boundary	———
Census tract centroid and tract number	+ 000

EXPERIMENTAL EDITION

ARY AND CENSUS TRACT MAP, 1970, NORFOLK S

1973

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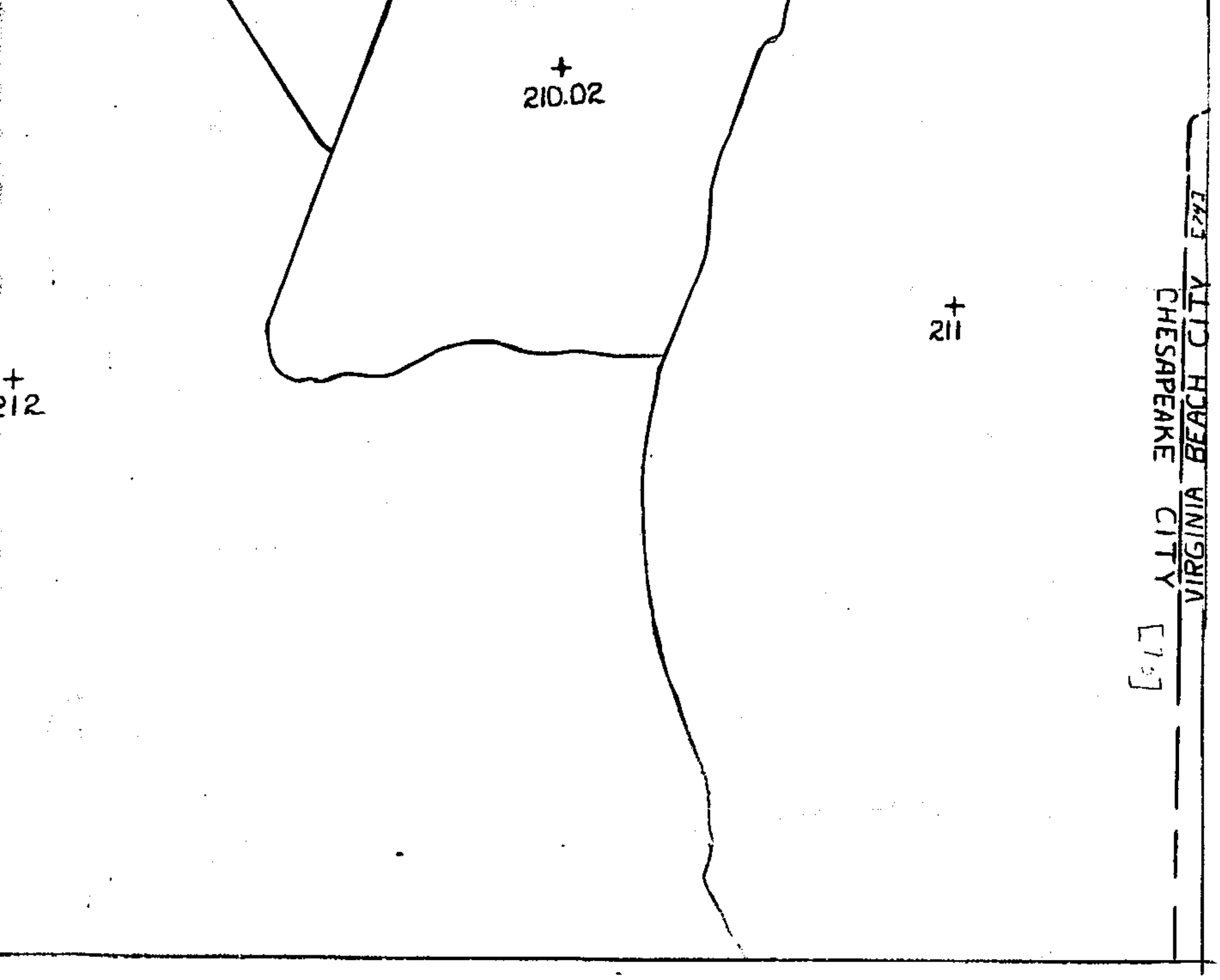

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0, NORFOLK SHEET, VA.

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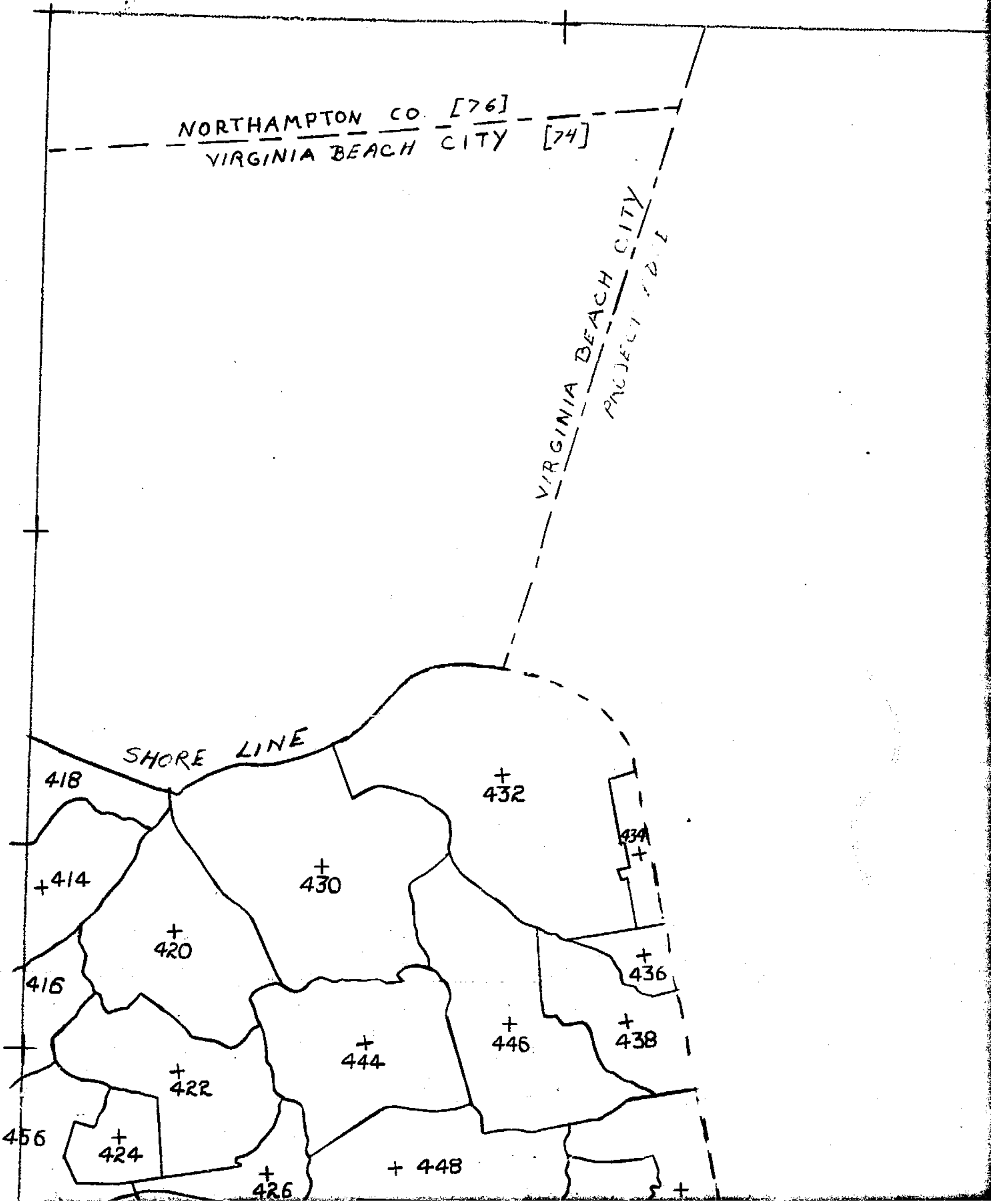
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY



FOLDOUT FRAME 2

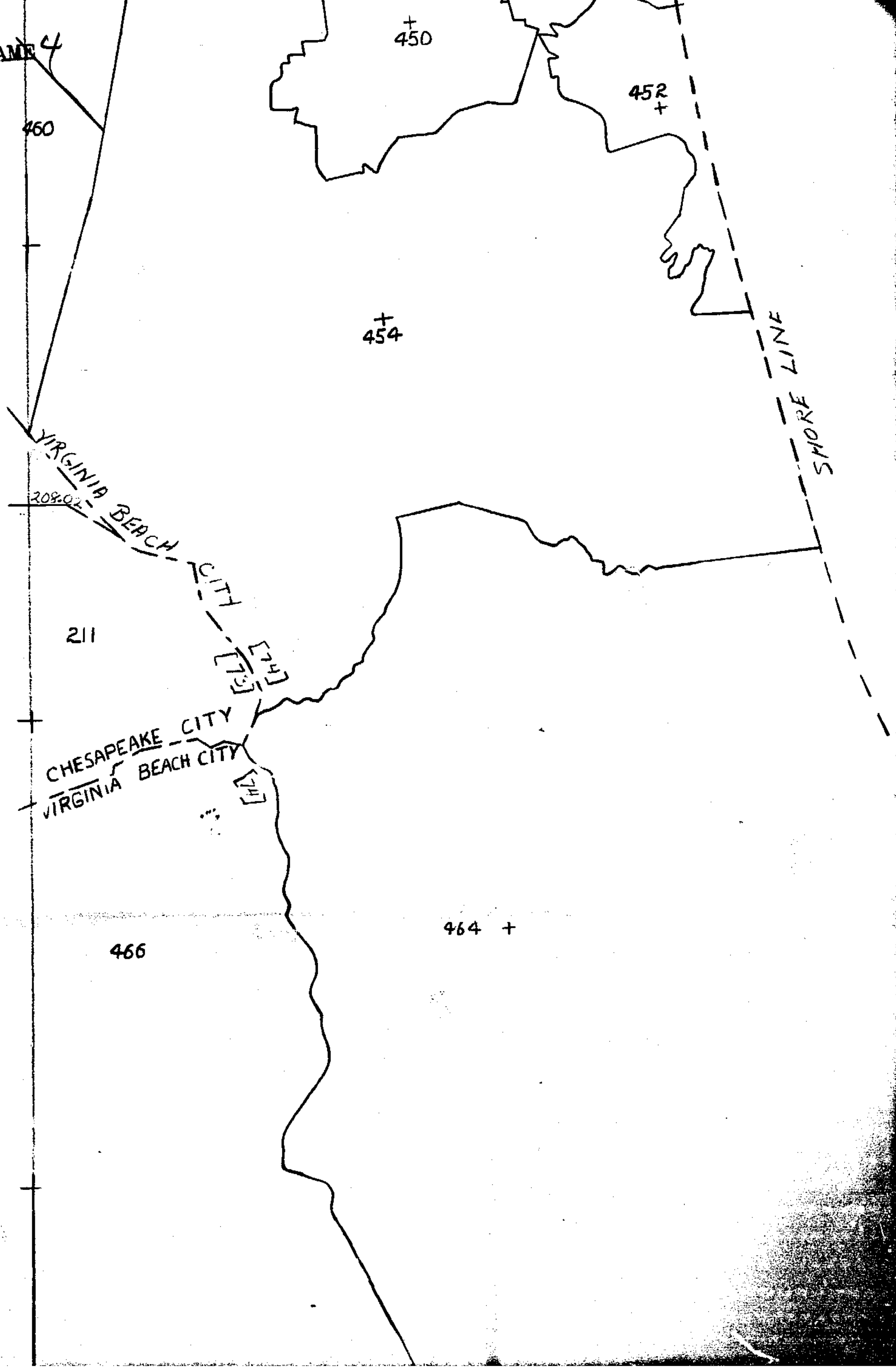
Plate 4

FOLDOUT FRAME 2

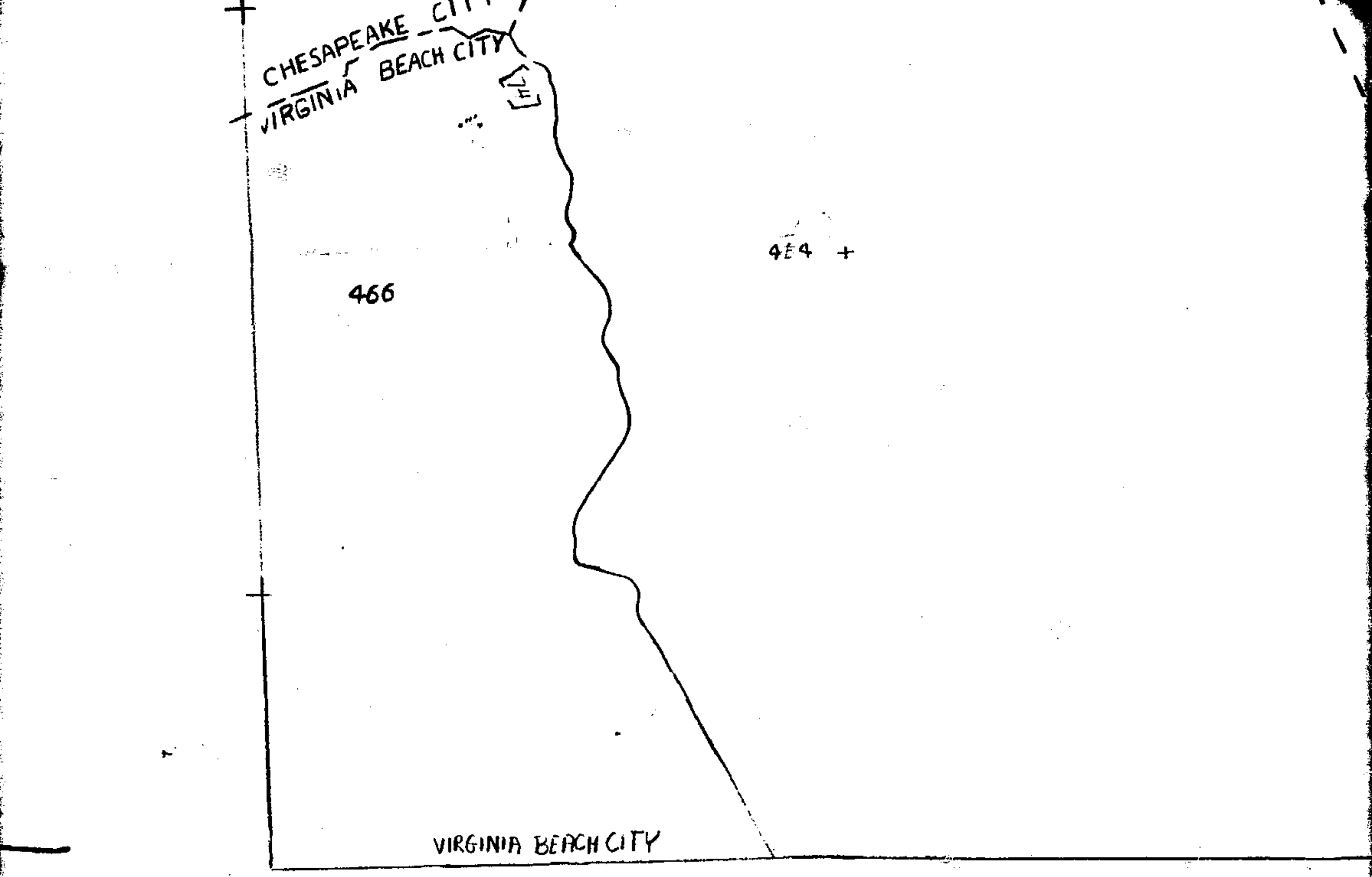
OUT FRAME 3

OPEN FILE MAP—1973

FOLDOUT FRAME 4



FOLDOUT FRAME 6



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County and inco
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Census tract da
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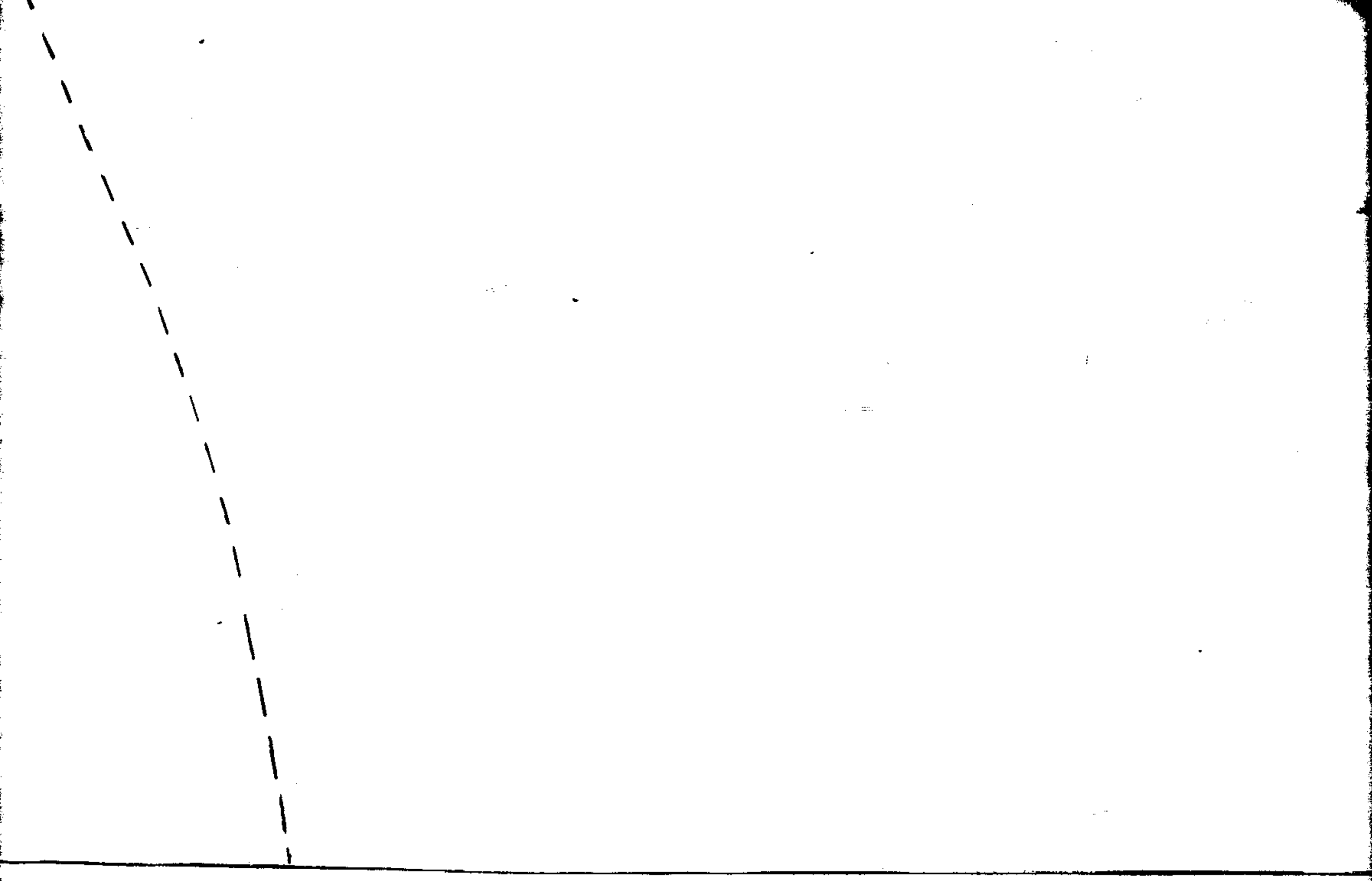
COUNTY BOUNDARY AND



SCALE 1:100 000

is keyed to the "Central Atlantic Regional Ecological Test Site Virginia Beach Sheet, Va. Land Use, 1970, Open —1973" which is gridded with both the UTM and Geographic Coordinate Systems.

nd incorporated city boundaries compiled by the U.S. Geological Survey from U.S.G.S. maps of the 1:250,000 ographic Map Series.

ract data compiled by the U.S. Geological Survey from U.S. Department of Commerce "U.S. Census of Popu- d Housing: 1970".

State boundary	
County boundary	
City boundary	
Census tract boundary	
Census tract centroid and tract number	+ 000

EXPERIMENTAL EDITION

CENSUS TRACT MAP, 1970, VIRGINIA BEACH SH

1973

FOLDOUT FRAME 8

70, Open

1:250,000

of Popu-

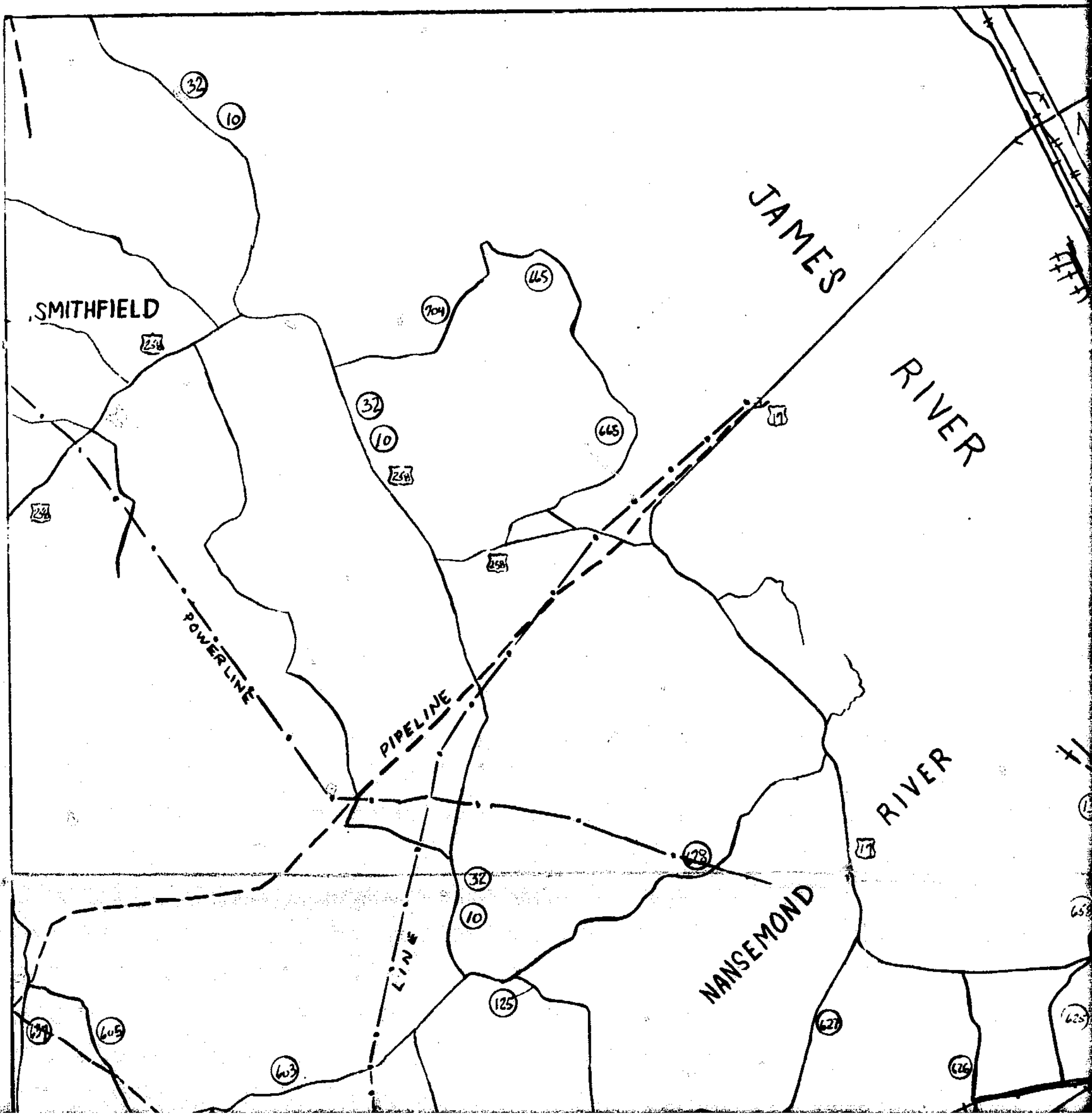
GINIA BEACH SHEET, VA.

FOLDOUT FRAME 9

FOLDOUT FRAME 1

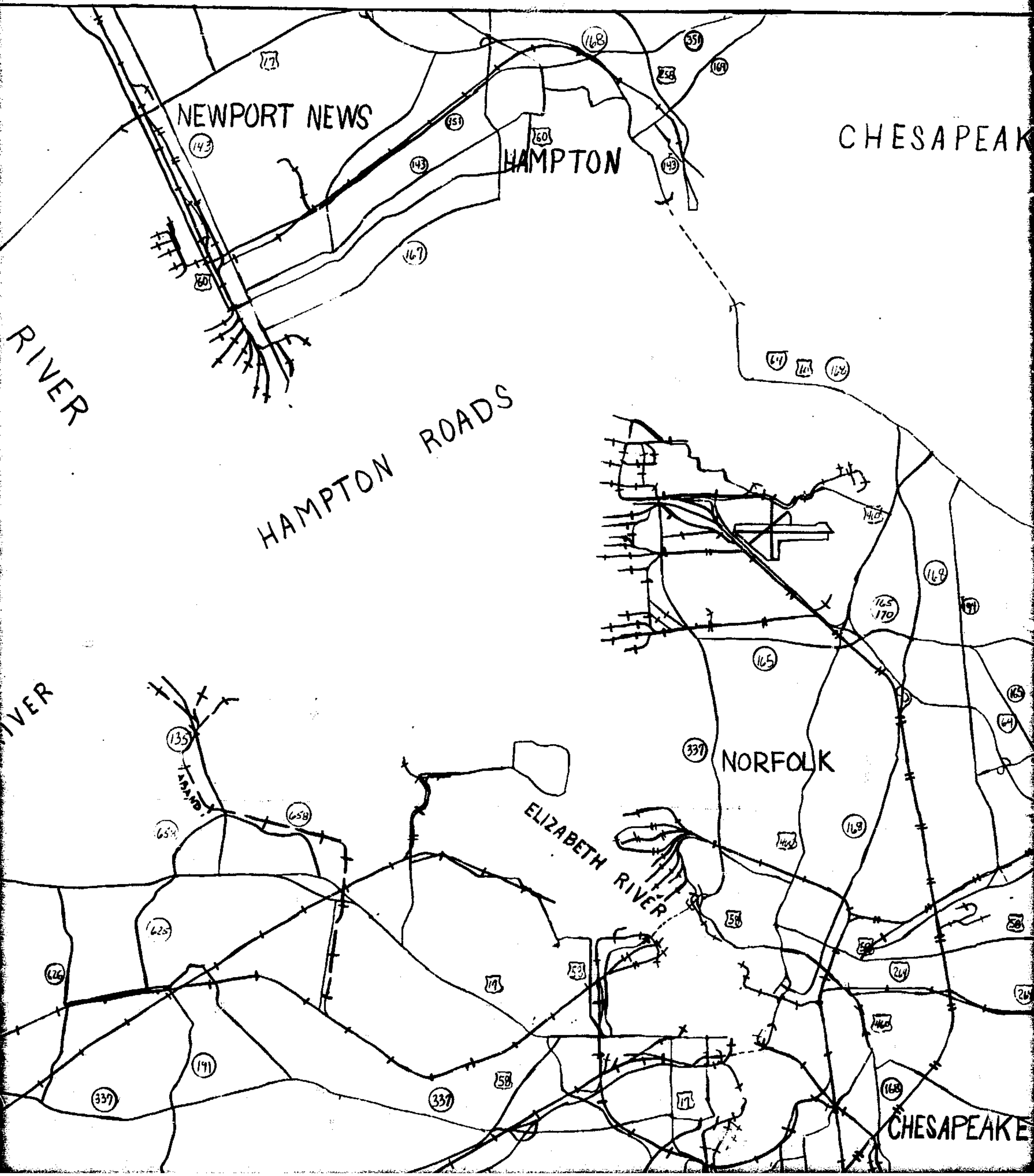
FOLDOUT FRAME 2

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY



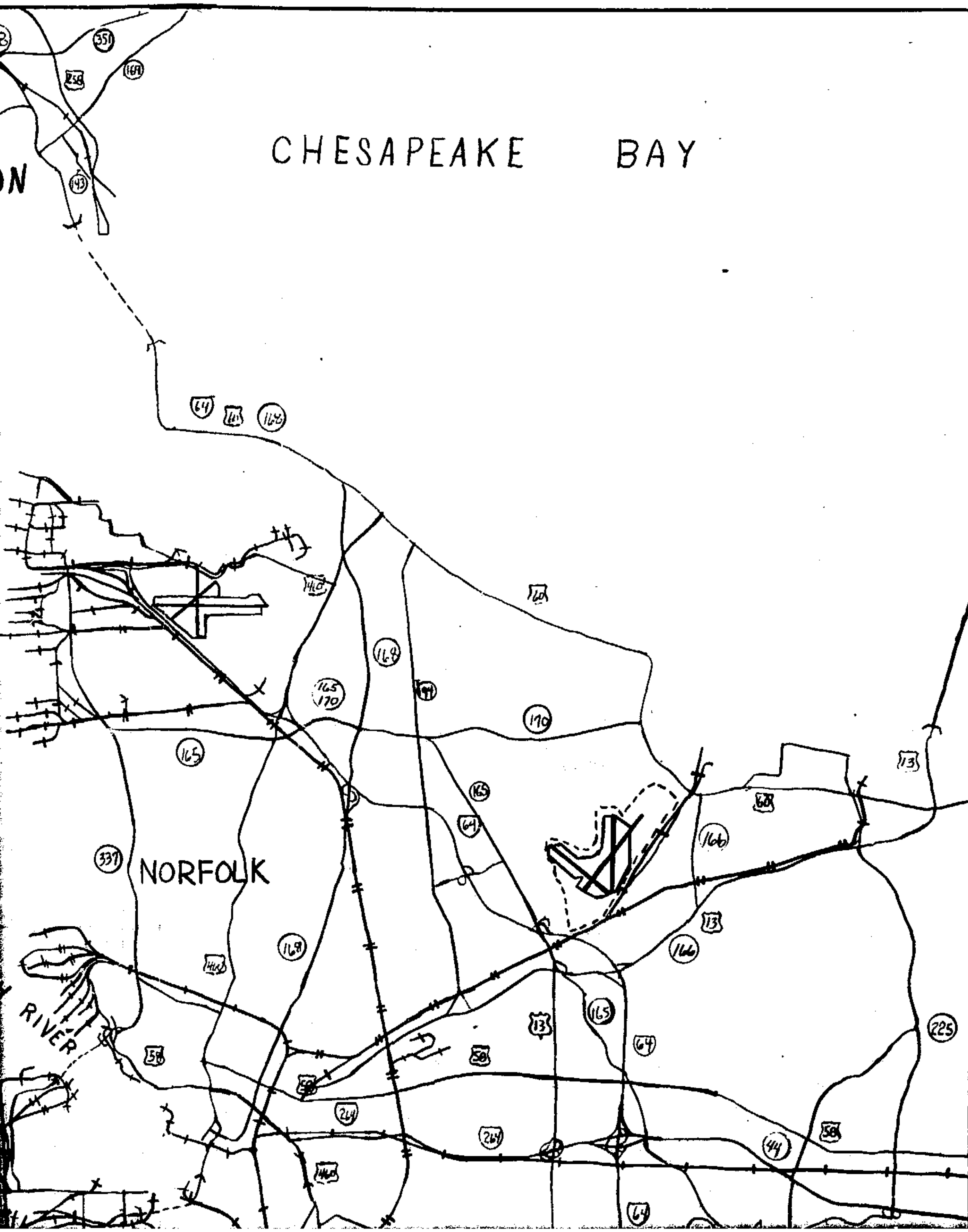
FOLDOUT FRAME 2

Plate 5

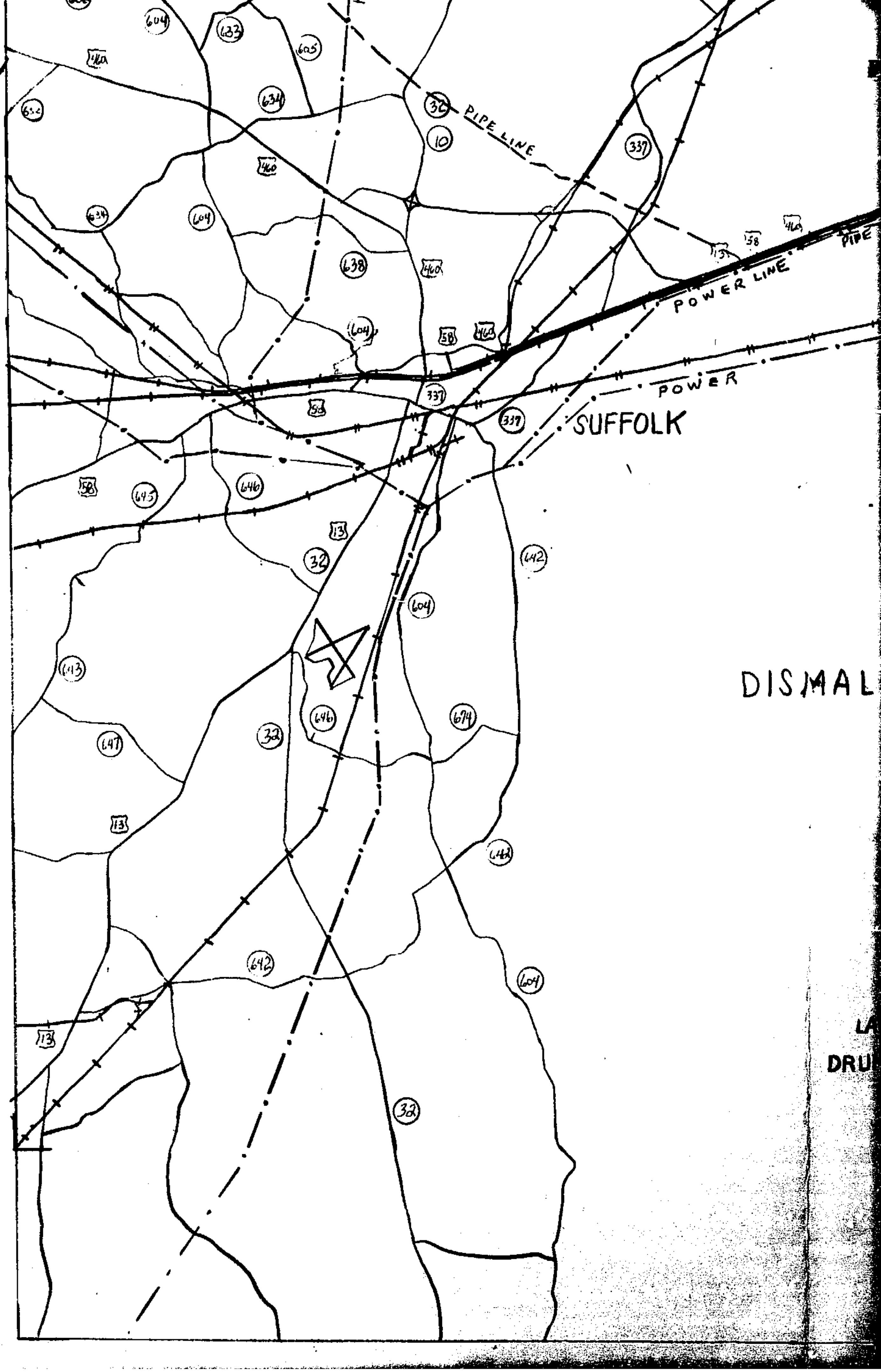


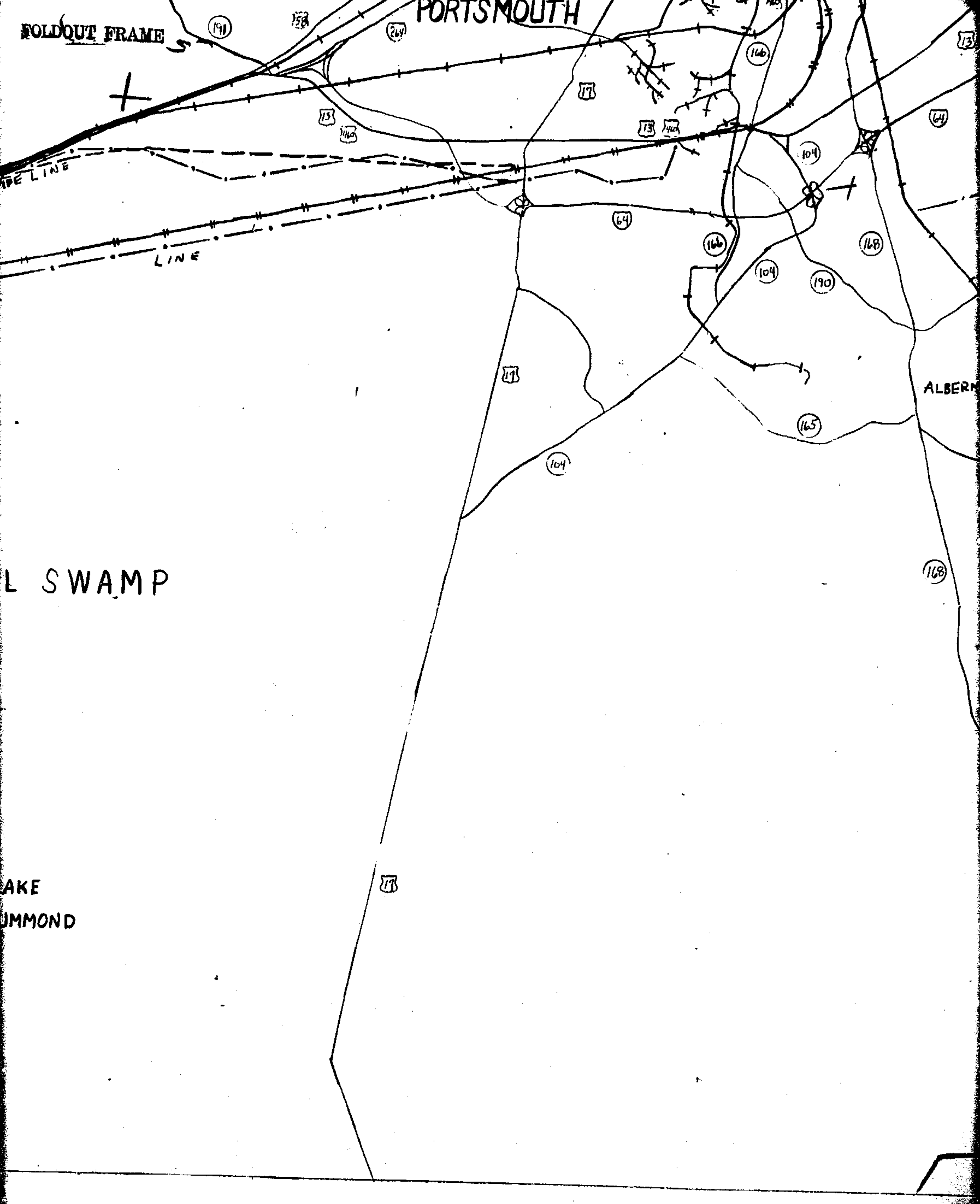
FOLDOUT FRAME 3

OPEN FILE MAP -1973



FOLDOUT FRAME 4





FOLDOUT FRAME 5
PORTSMOUTH
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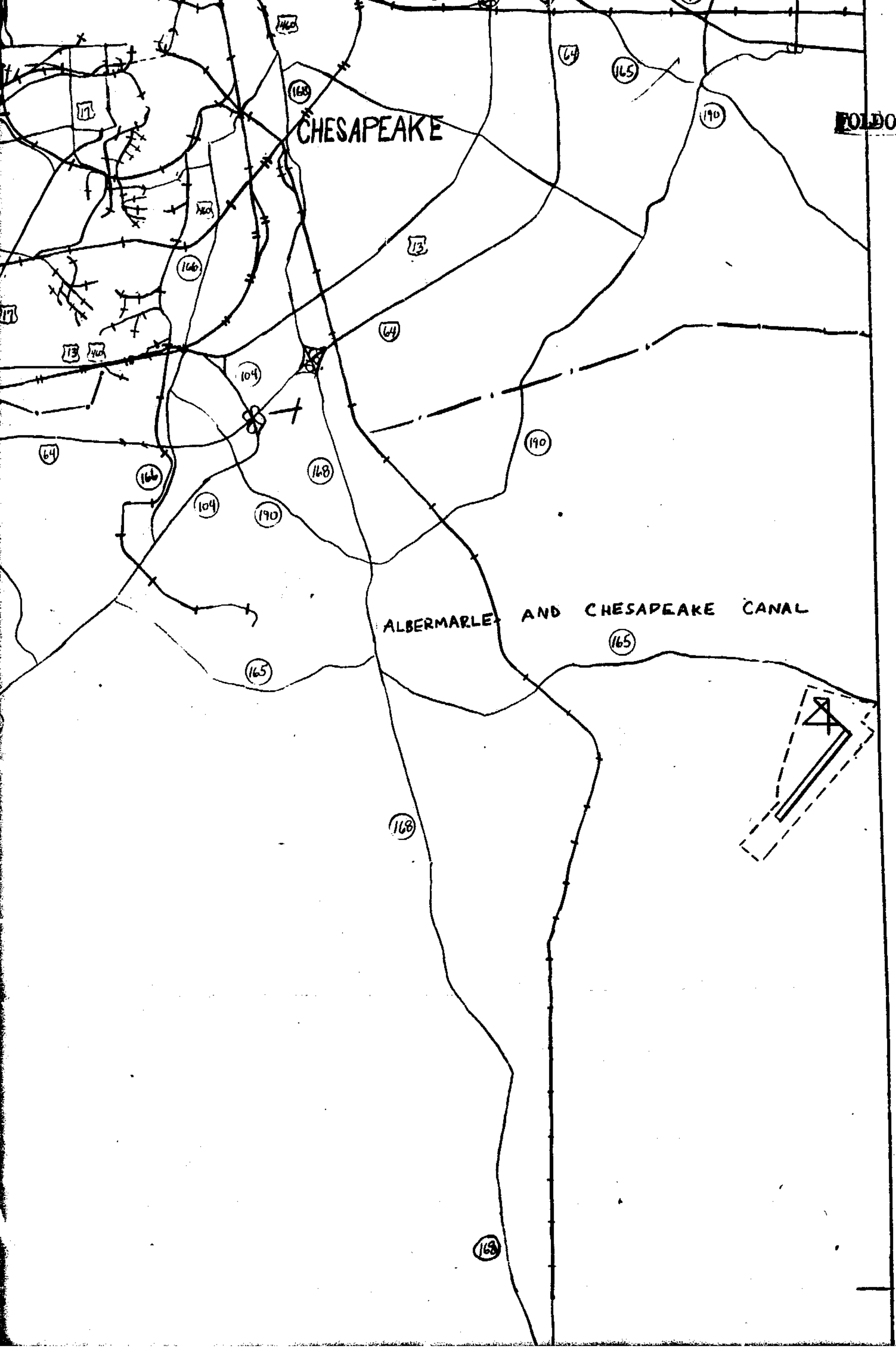
SCALE 1:100 000

FOLDOUT FRAME 6



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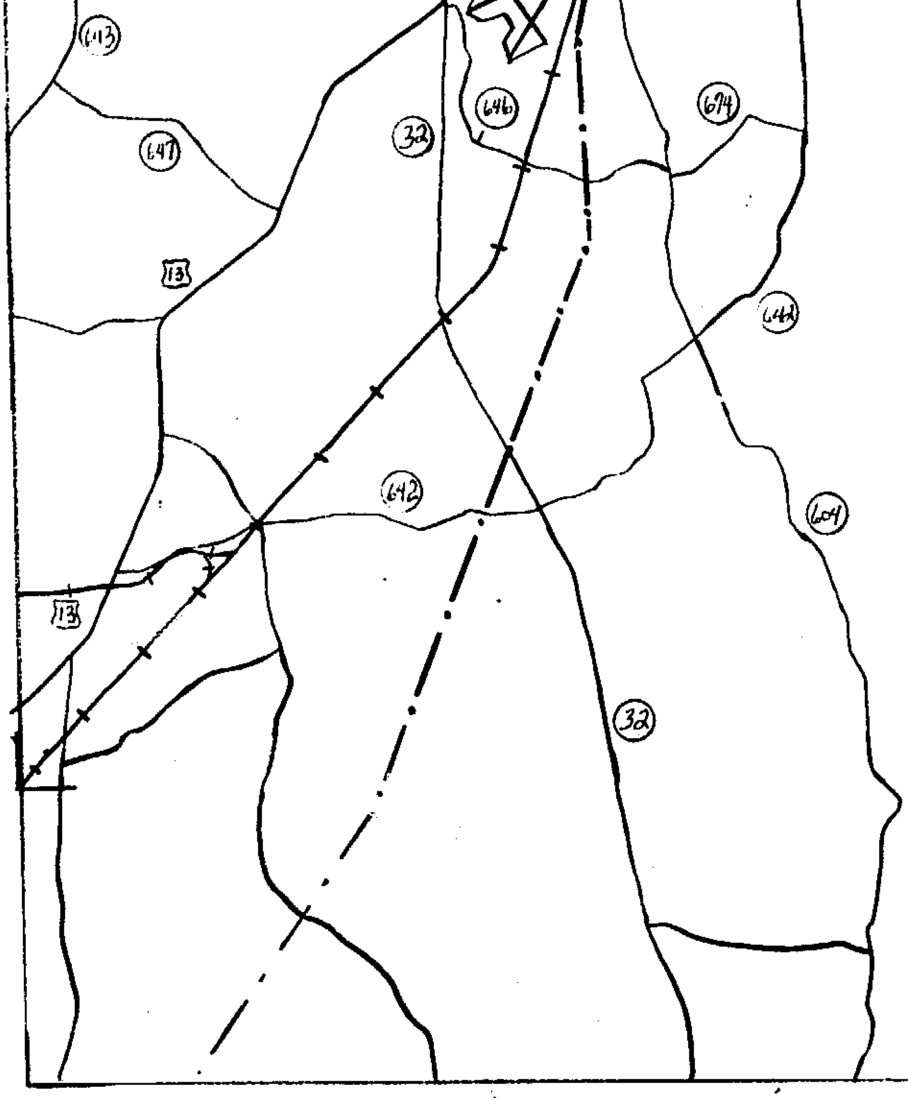

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CULTURAL

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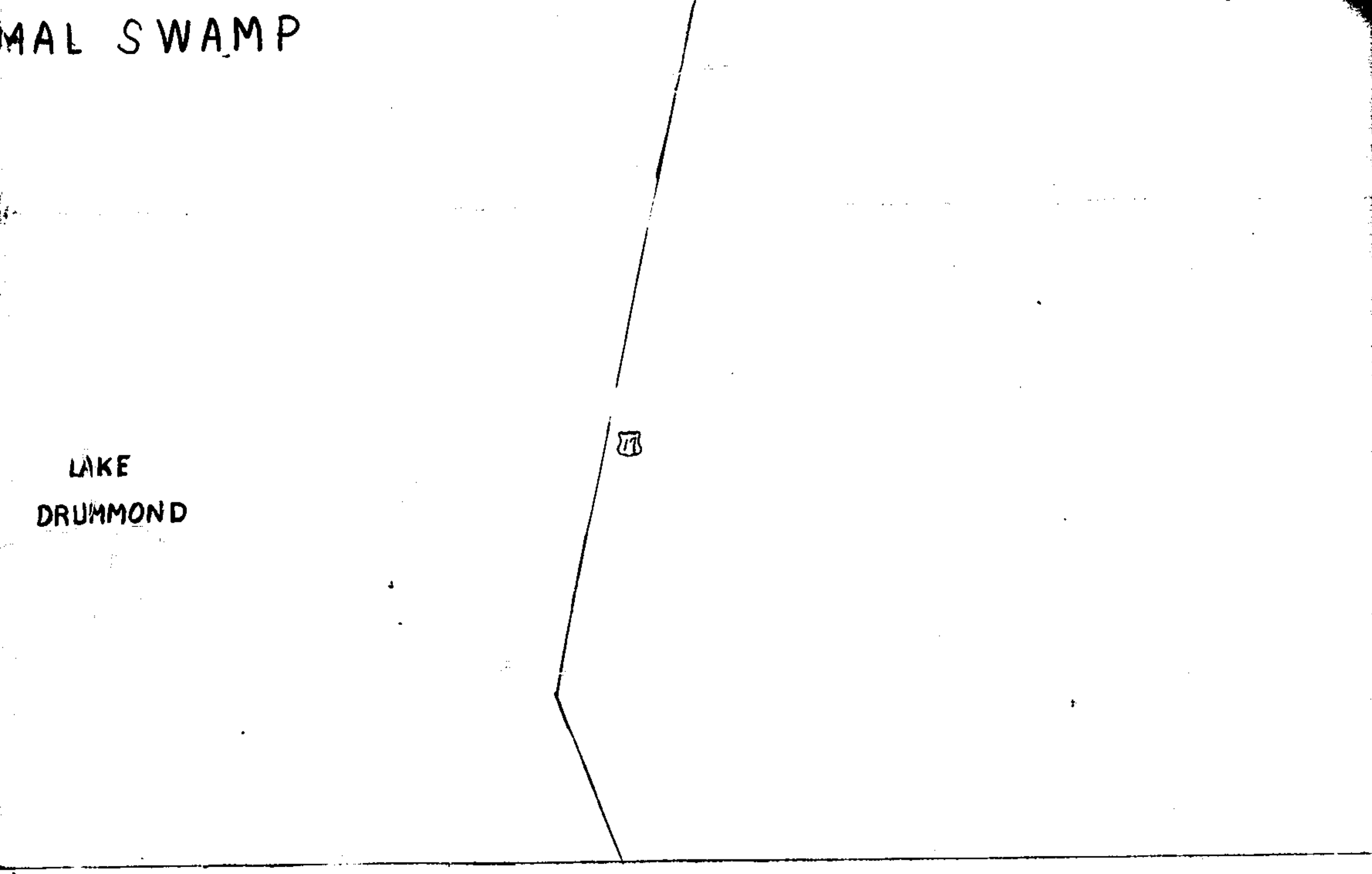


SCALE 1:100 000

This map is keyed to the "Central Atlantic Regional Ecological Test Site Norfolk Sheet, Va. Land Use, 1970, Open File Map—1973" which is gridded with both the UTM and Geographic Coordinate Systems.

Cultural Feature data compiled by the U.S. Geological Survey from U.S.G.S. maps of the 1:250,000 and 1:24,000 scale Topographic Map Series.

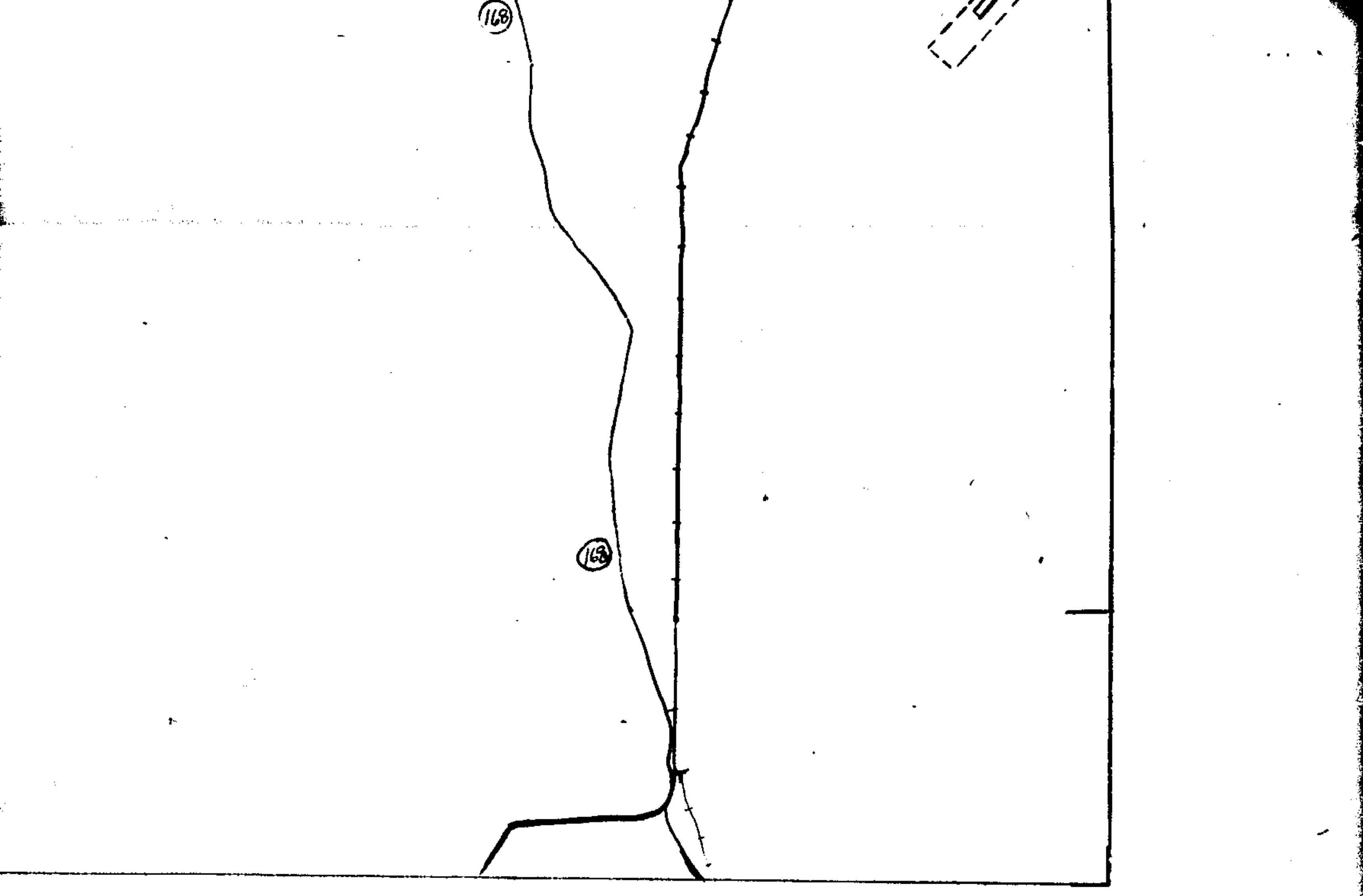
Cultural information symbols are the same as those used by the U.S. Geological Survey for topographic maps unless otherwise indicated.

EXPERIMENTAL EDITION

AL FEATURES MAP, 1970, NORFOLK SHEET, VA.

1973

FOLDOUT FRAME 8



e, 1970, Open File

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phic maps unless

LK SHEET, VA.

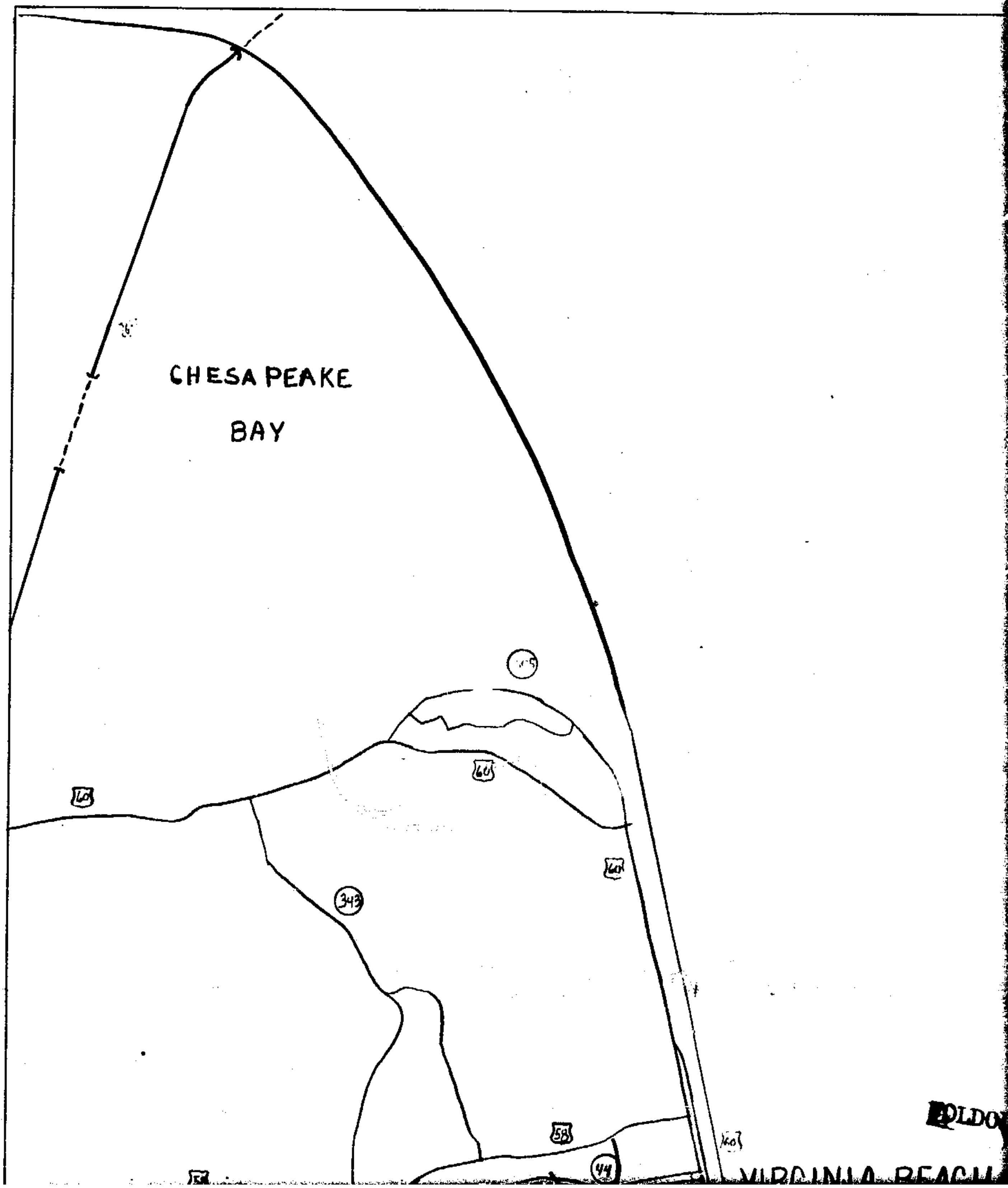
FOLDOUT FRAME

FOLDOUT FRAME 1

PLATE 6

[redacted]

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY



FOLDOUT FRAME 2

Plate 6

FOLDOUT FRAMES

ATLANTIC

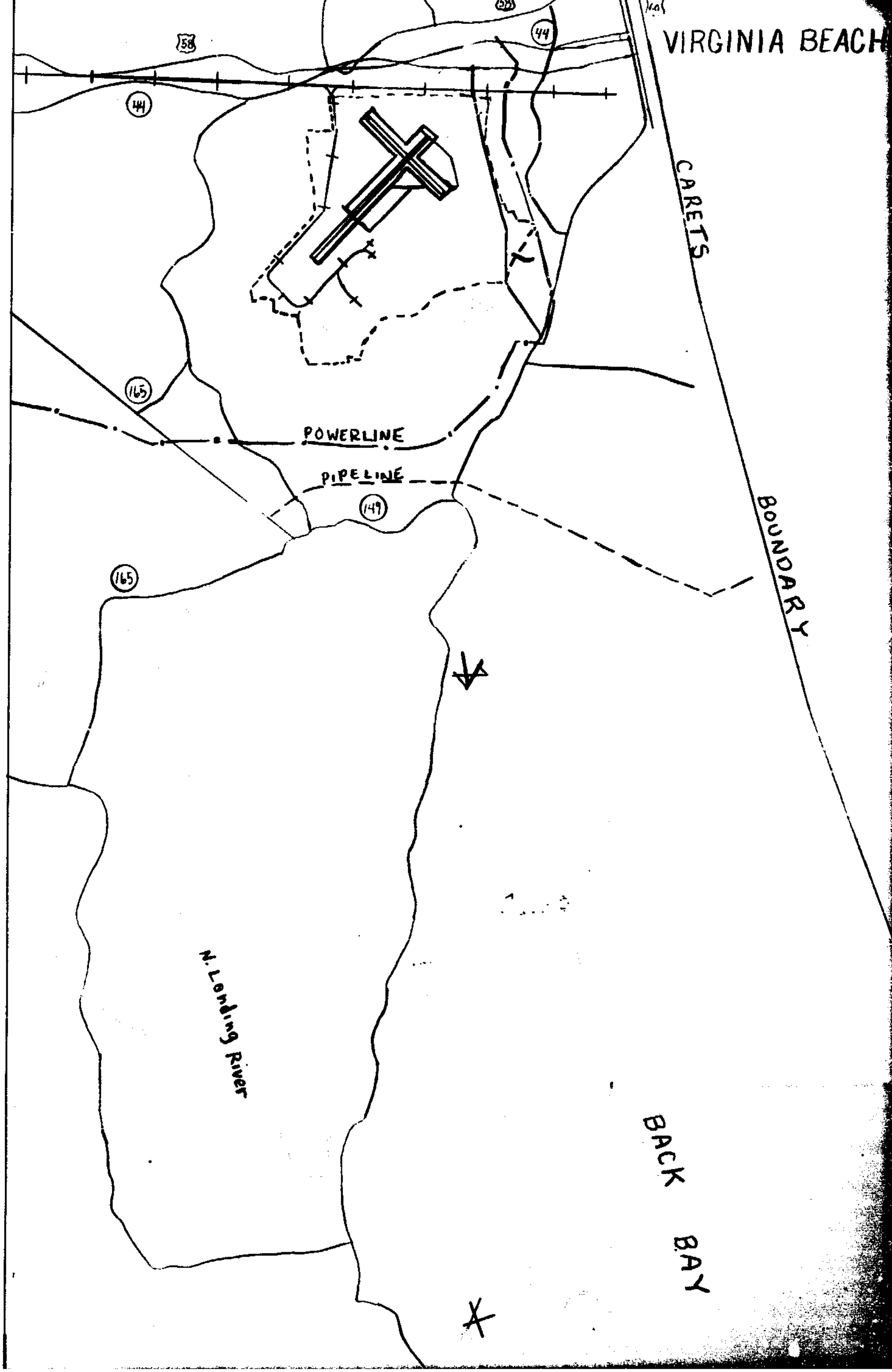
BEACH

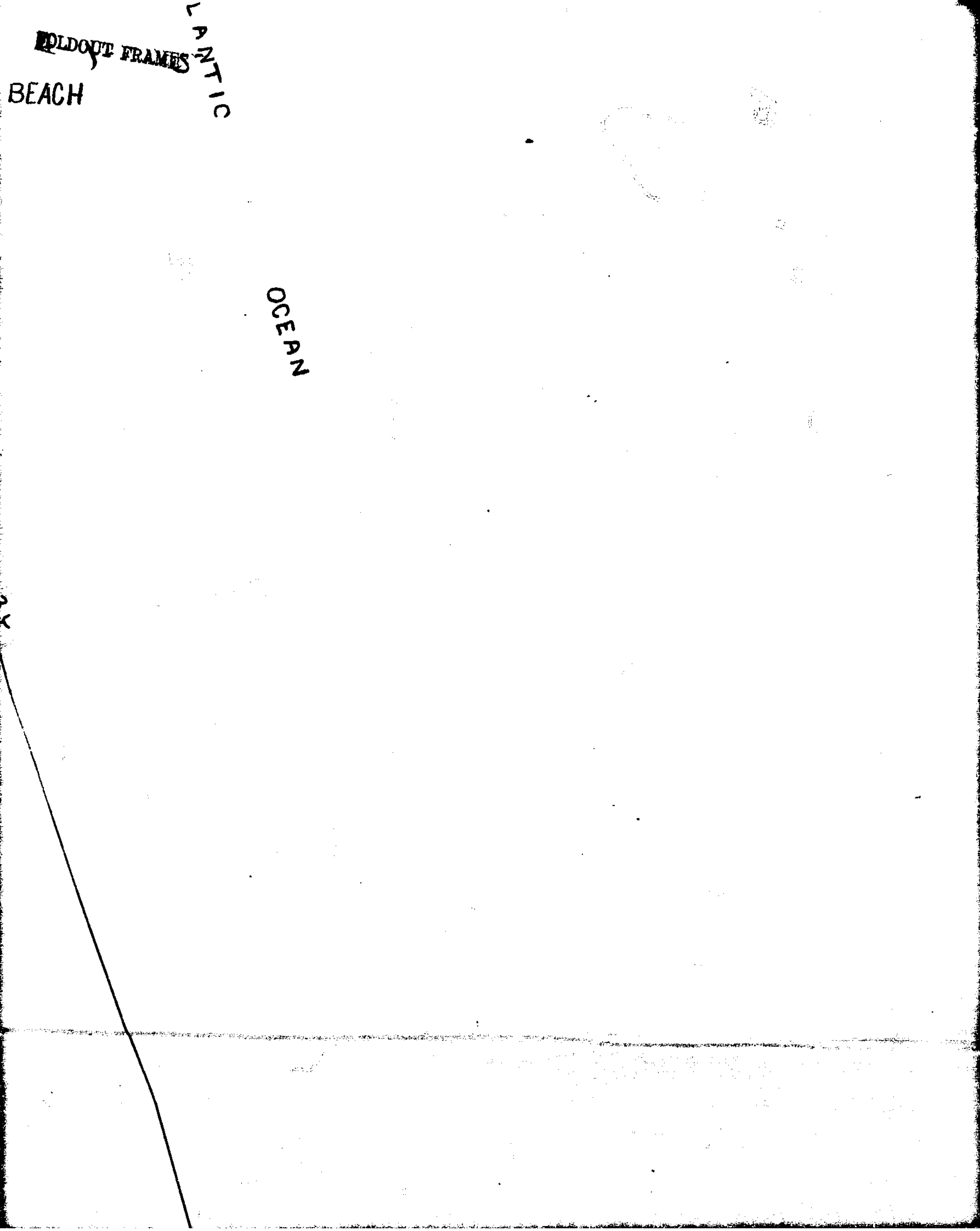
FOLDOUT FRAME 3

OPEN FILE MAP—1973

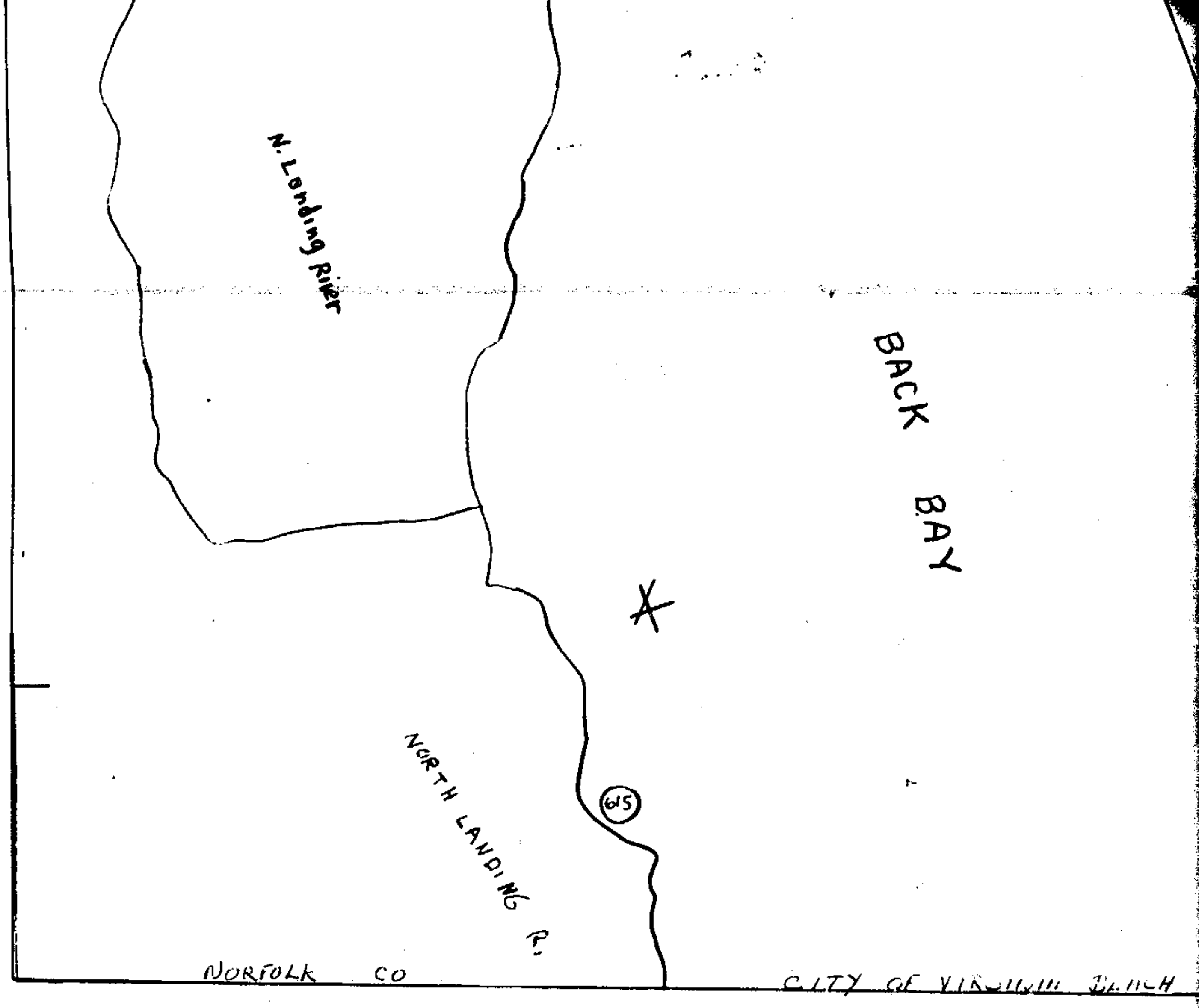
FOLDOUT FRAME 2

FOLDOUT FRAME 4




BEACH
LANTIC
OCEAN

FOLDOUT FRAME 2



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File Map—197

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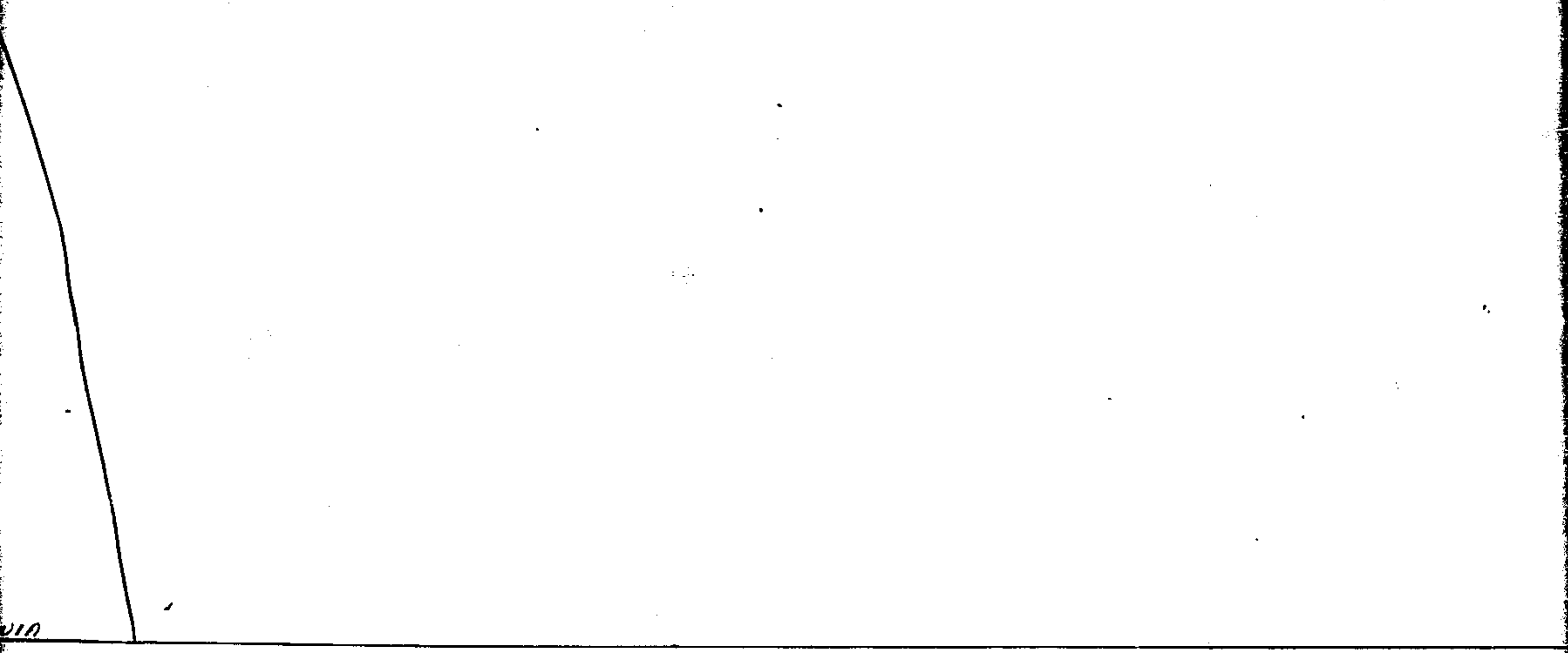
FOLDOUT FRAME 7



SCALE 1:100 000

 entral Atlantic Regional Ec[illegible]cal Test Site Virginia Beach Sheet, Va. Land Use, 1970, Open
dded with both the UTM and Geographic Coordinate Systems.

ed by the U.S. Geological Survey from U.S.G.S. maps of the 1:250,000 and 1:24,000 scale

s are the same as those used by the U.S. Geological Survey for topographic maps unless

EXPERIMENTAL EDITION

MAP, 1970, VIRGINIA BEACH SHEET, VA.
1973

FOLDOUT FRA

970, Open

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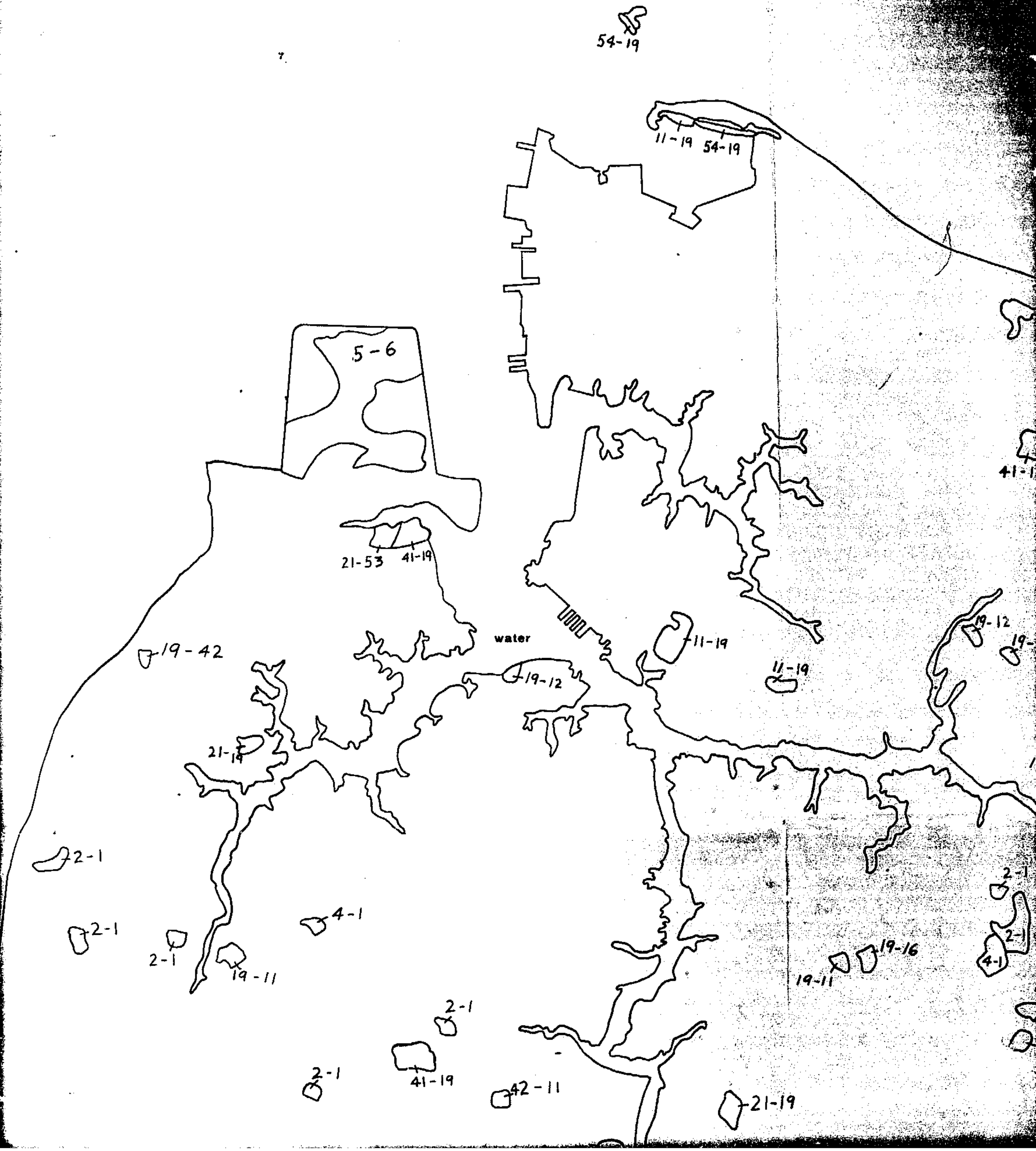
ACH SHEET, VA.

FOLDOUT FRAME 9

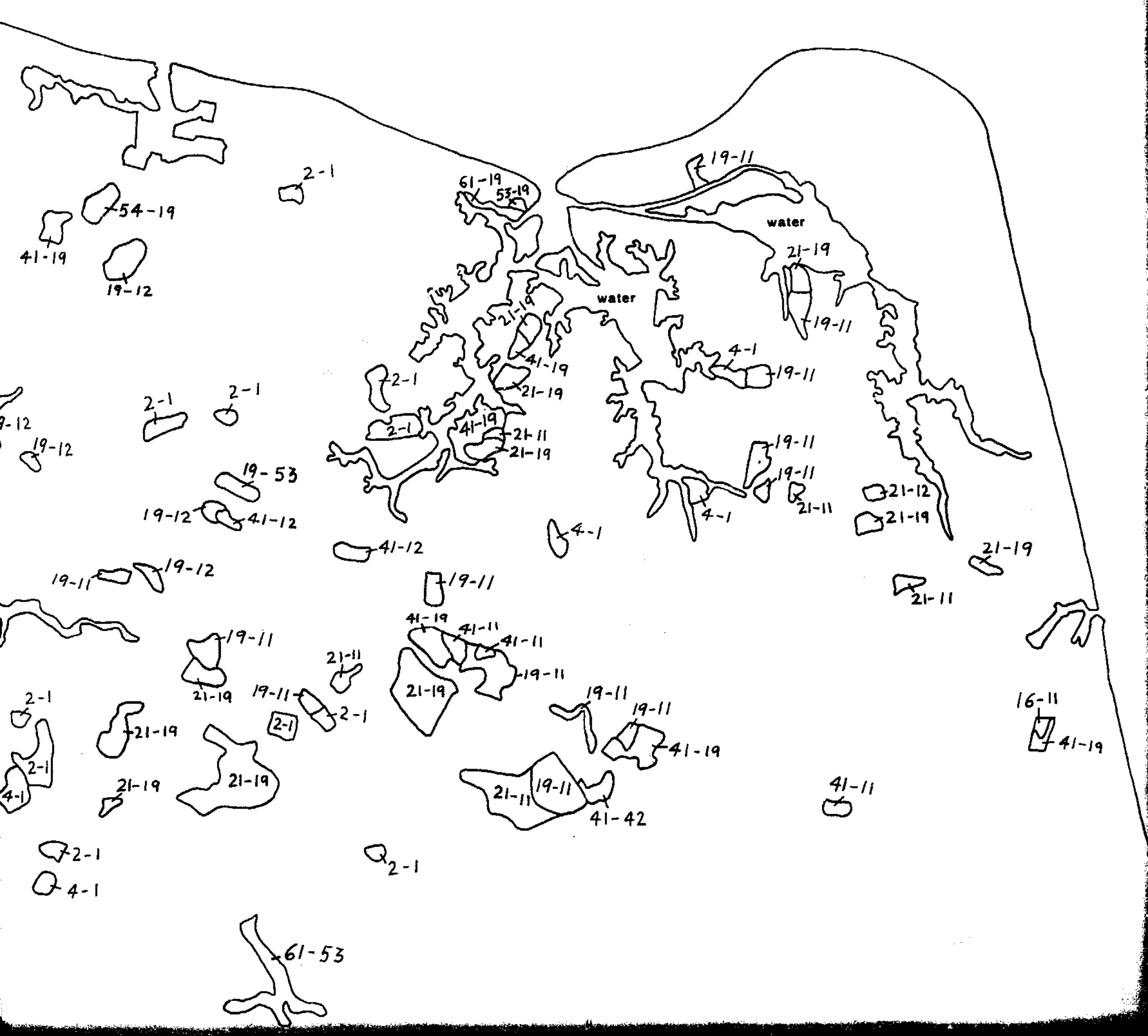
FOLDOUT FRAME

ERTS / Aircraft Detected



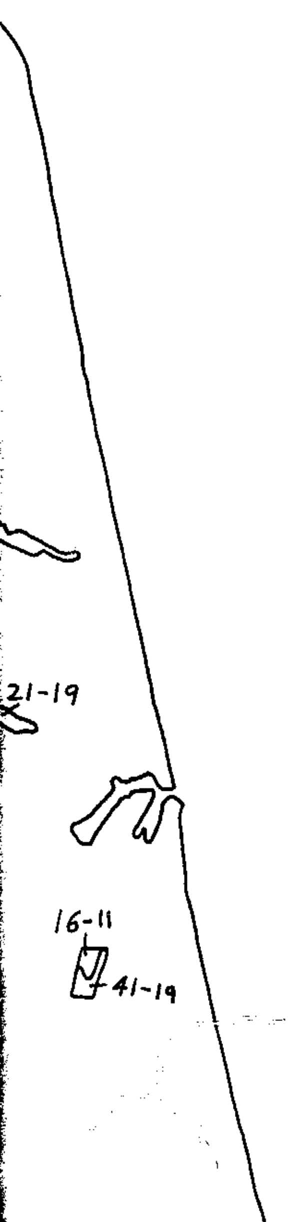
FOLDOUT FRAME 2

evel I and II Land Use Char



FOLDOUT FRAME 3

Changes, 1970-1972

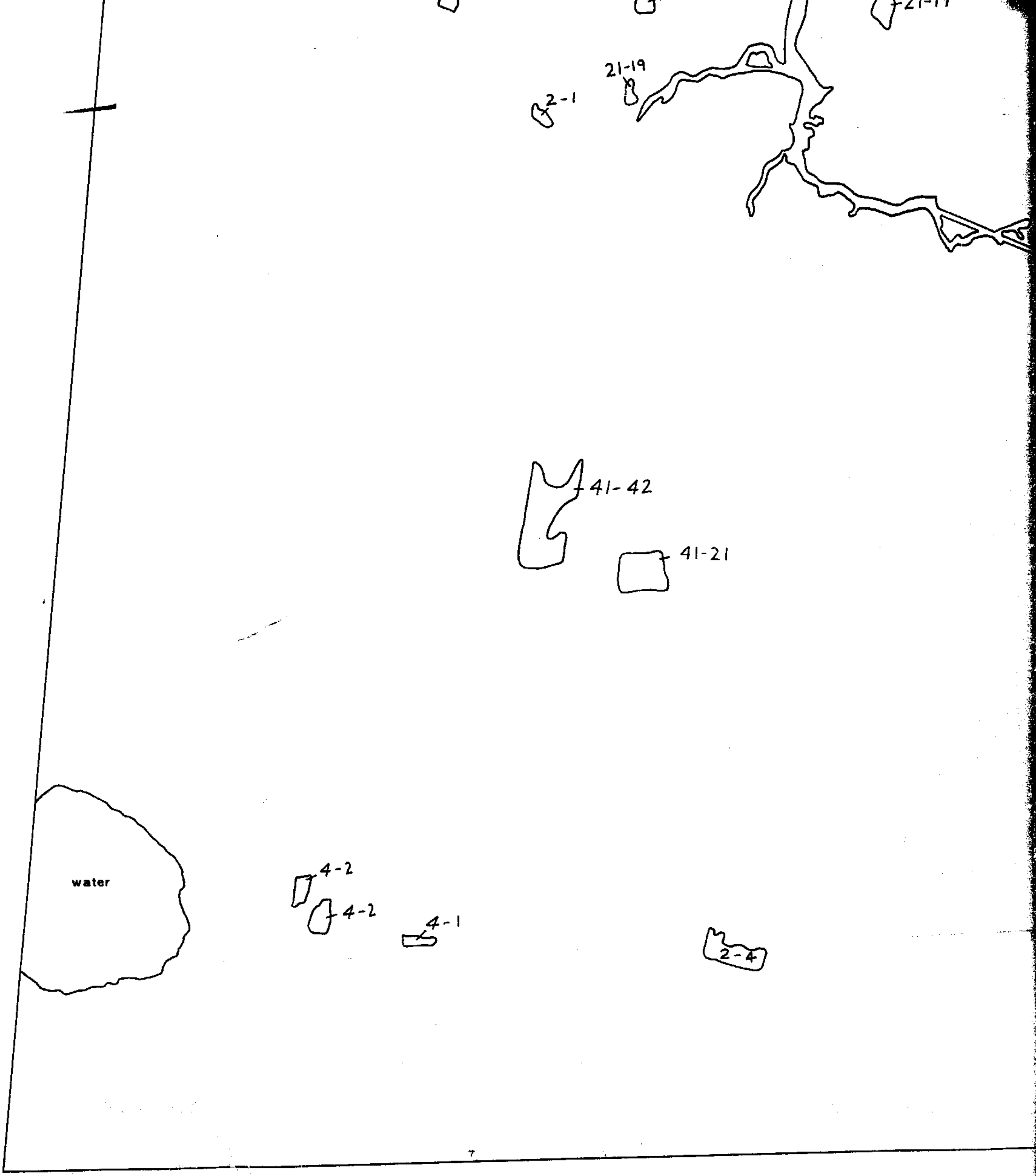


NORFOLK TEST SITE

1972

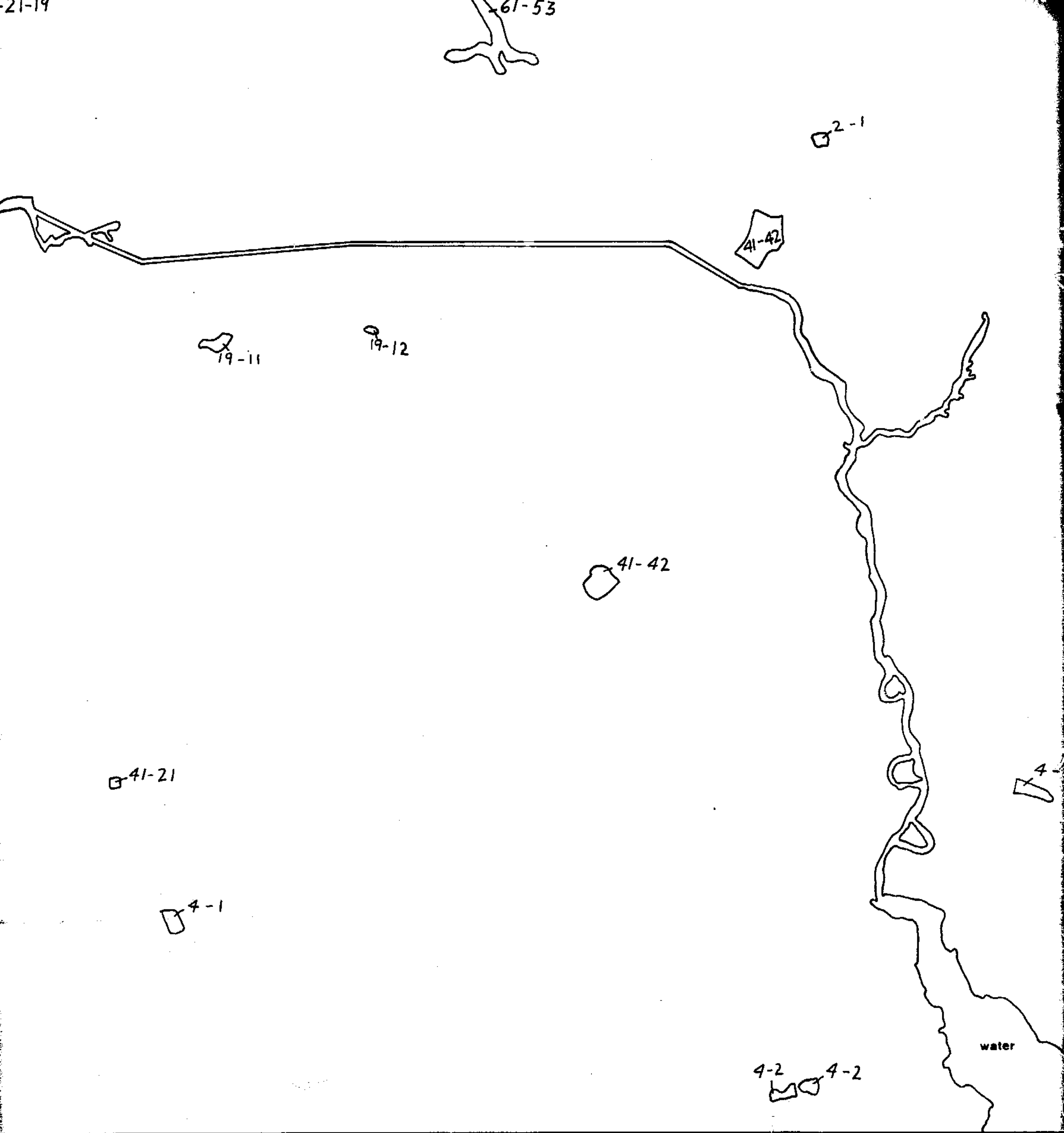
LAND USE CATEGORIES

	Level I	Level II
Urban and Built-up	1	
Residential		11
Commercial and services		12
Institutional		16
Open and other		19
Agricultural Land	2	
Cropland and pasture		21
Forest Land	4	
Heavy crown cover		41
Light crown cover		42
Water	5	
Reservoirs		53
Bays and estuaries		54
Nonforested Wetland	6	
Vegetated		61



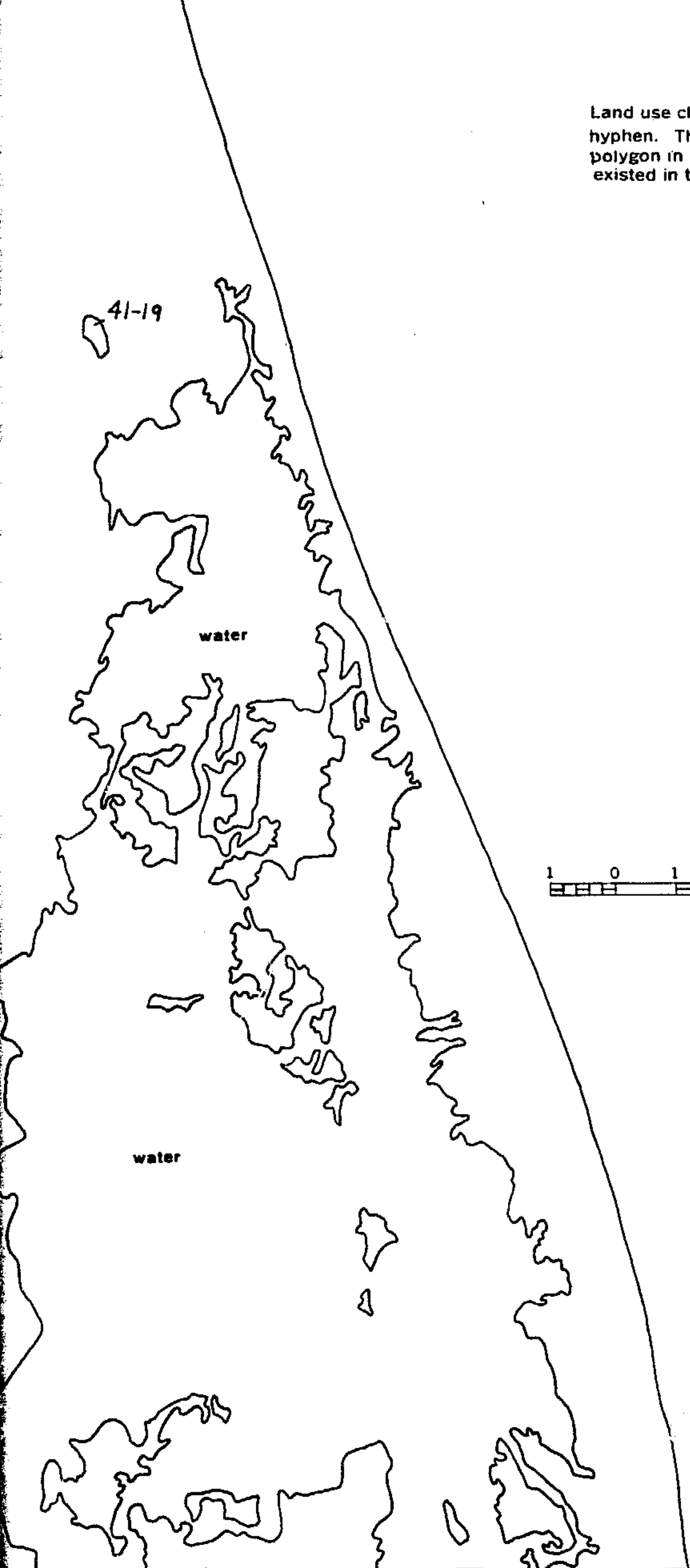
U. S. GEOLOGICAL SURVEY

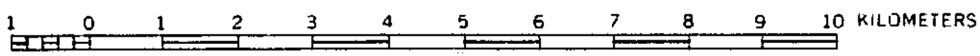
FOLDOUT FRAME 4

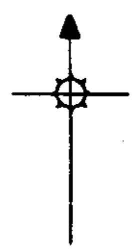


FOLDOUT FRAME 5

Land use change polygons are identified by two numbers separated by a hyphen. The first number indicates the land use which existed in a polygon in 1970. The second number indicates the land use which existed in that polygon in 1972.







FOLDOUT FRAME 2

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

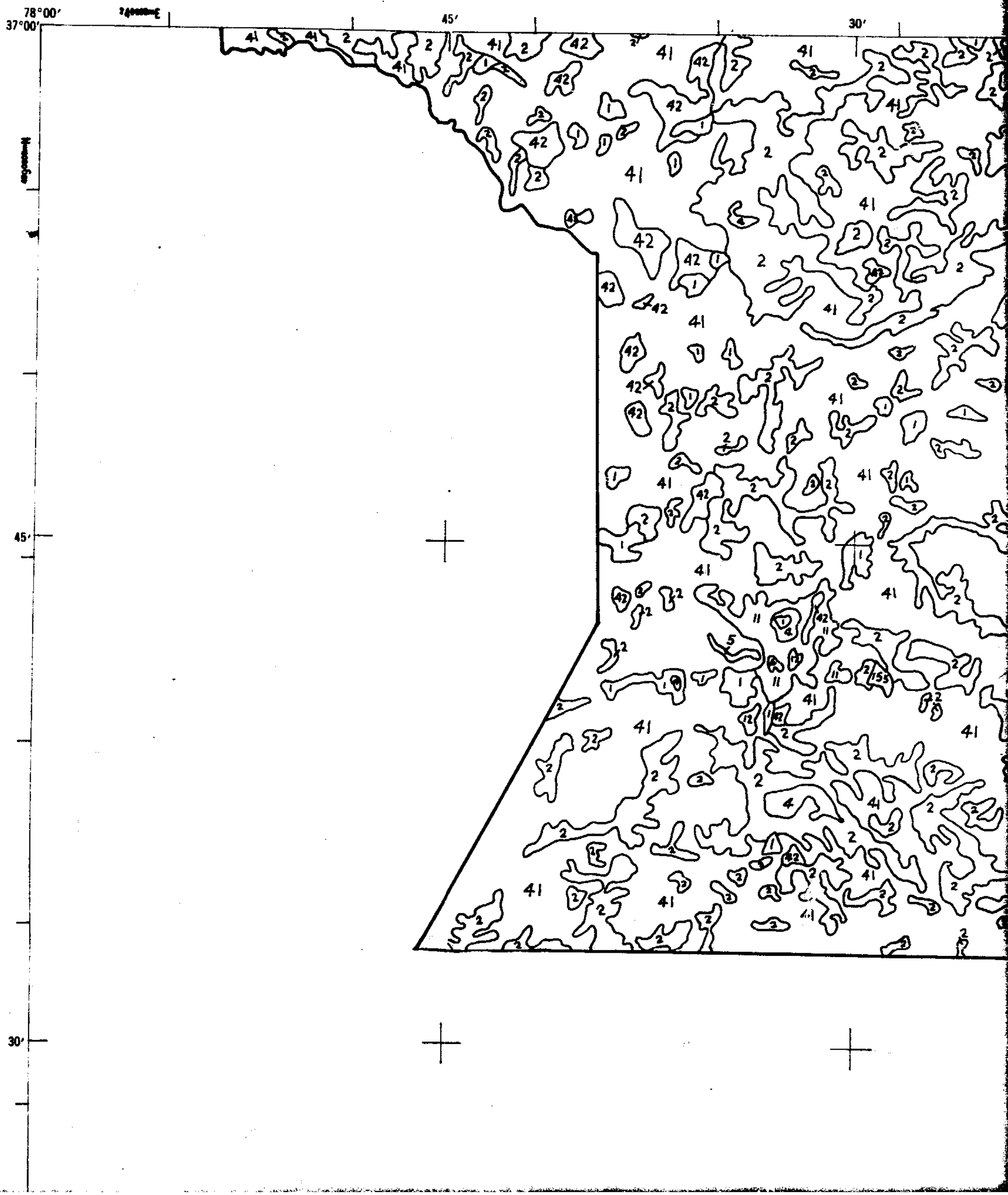
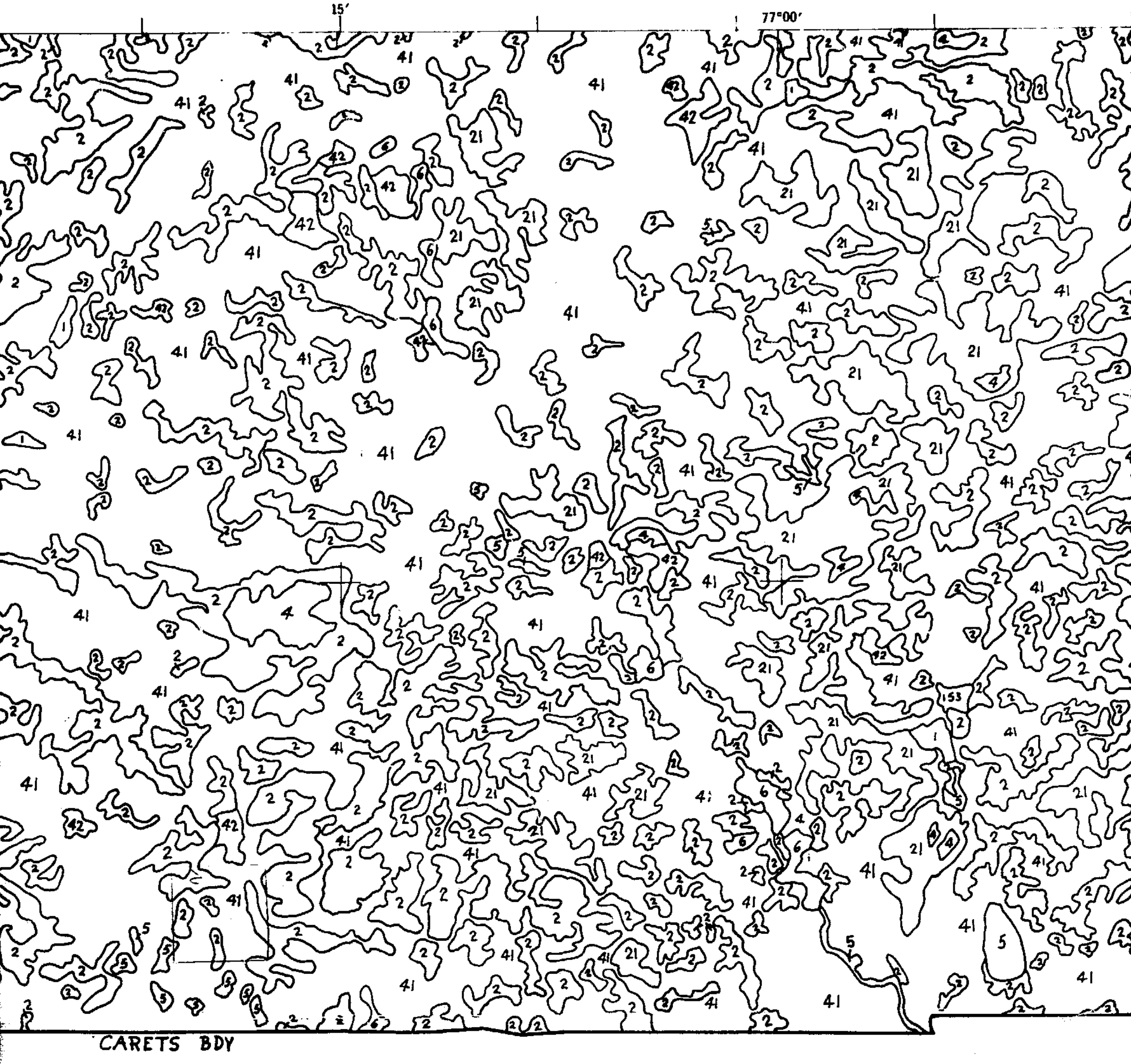


Plate 8

ERTS LAND USE, 1972



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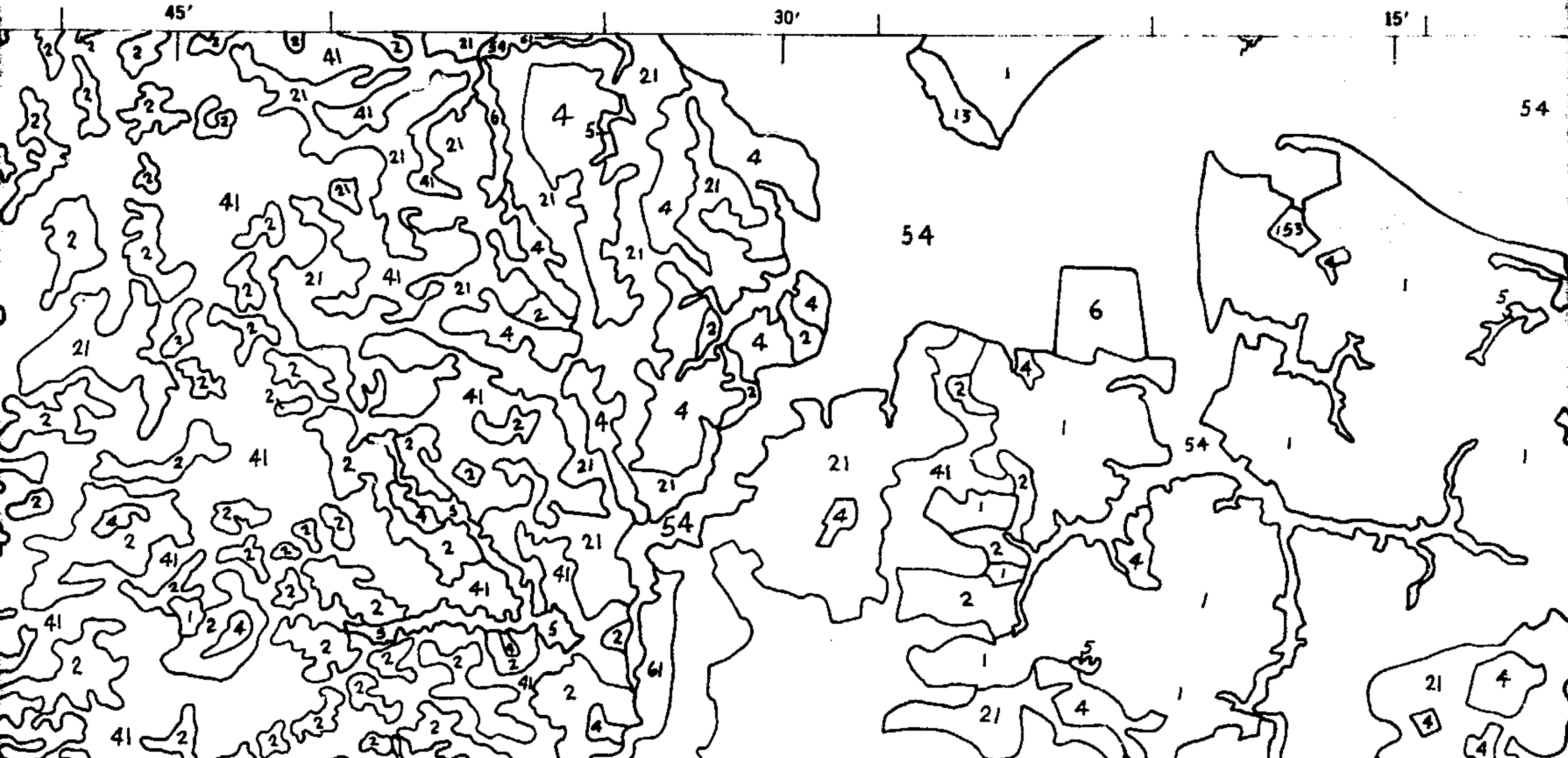
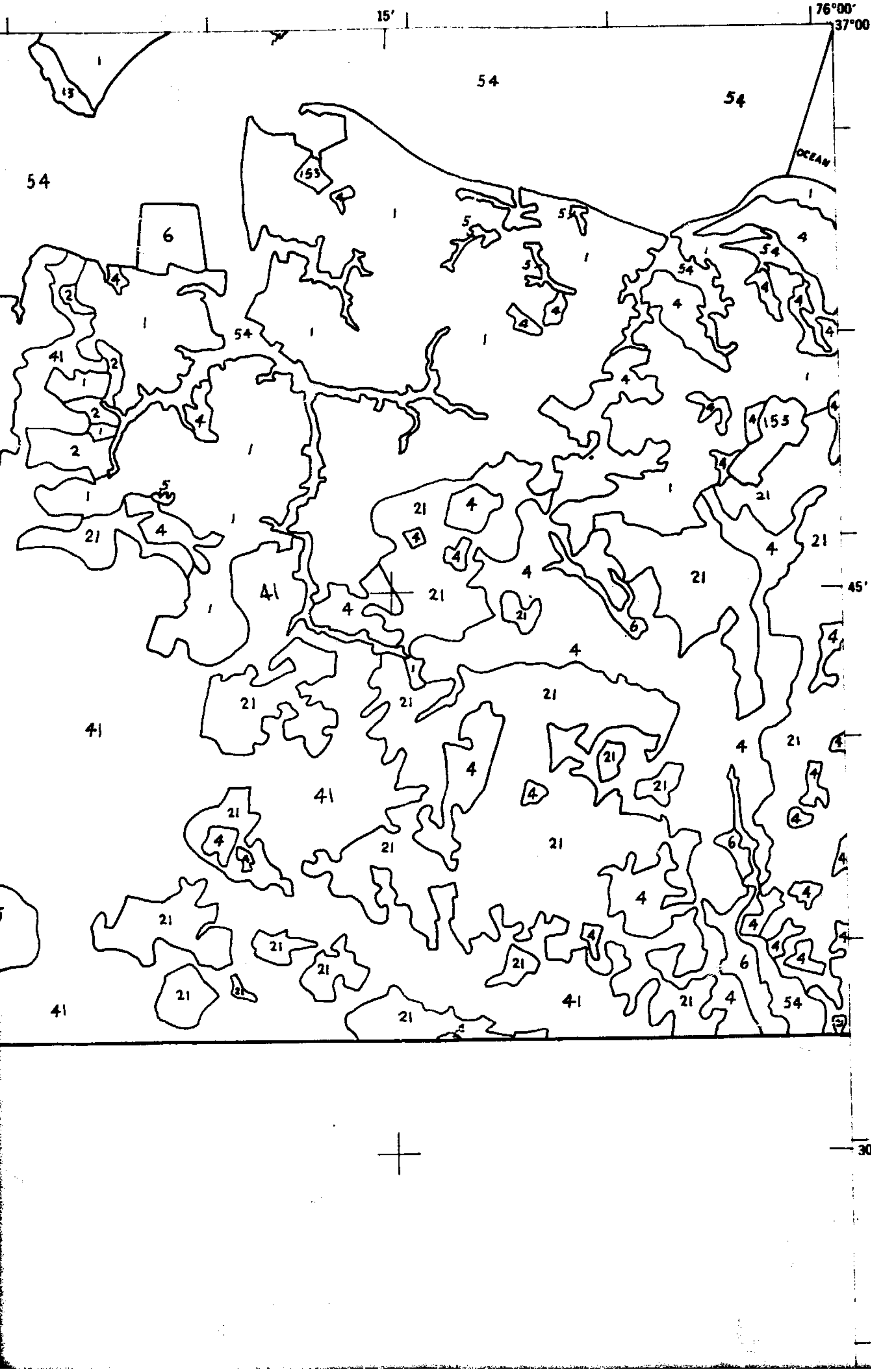
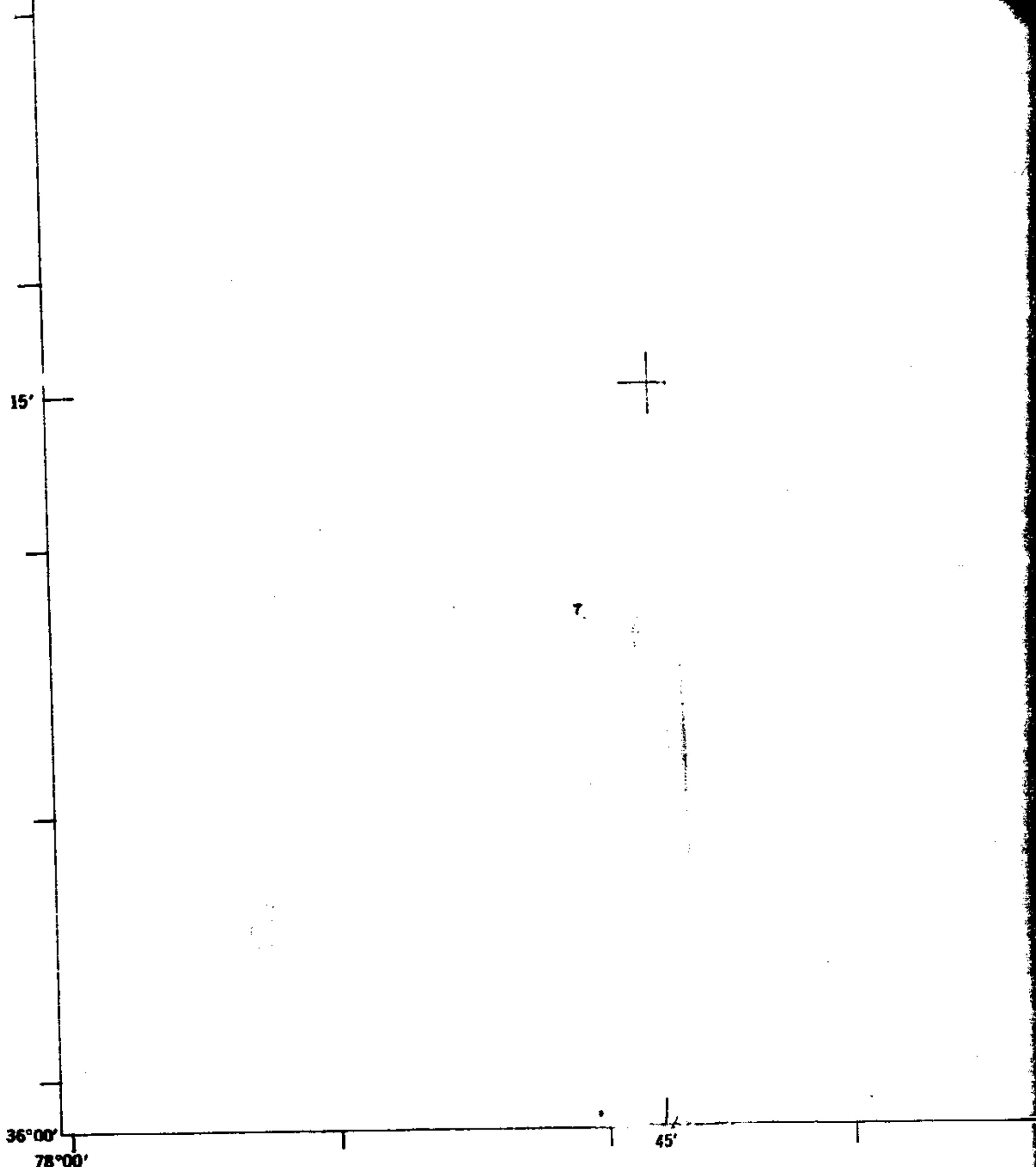



15'
76°00'
37°00'
45'
30'
OCEAN
54
1
13
153
6
2
41
4
5
21
155



This overlay is keyed to the U.S. Geological Survey 1:250,000-scale topographic map.

Land-use data were compiled by the U.S. Geological Survey from 1:250,000-scale Earth Resources Technology Satellite-1 images acquired by the National Aeronautics and Space Administration, 1972.

Land-use classification categories are in general conformance with those proposed by the Inter-Agency Steering Committee on Land Use Information and Classification in U.S. Geological Survey Circular 671 (1972). This compilation is not edited or field checked.

15-minute geographic projection ticks and 10,000 meter ticks: Universal Transverse Mercator, Zone 18, 1927 North American datum.

E

URBAN AND BUILT-UP
Residential
Single-Family
Commercial and Se
Industrial
Extractive
Transportation, C
and Utilities
Highways, Aut
Terminals,
and Other
Railroads and
Facilities
Airports
Institutional
Strip and Cluster
Mixed
Open and Other

FOLDOUT FRAME 5

30′ 15′ 77°00′

LAND-USE CLASSIFICATION
(Levels II and III are shown where identified)

1	AGRICULTURAL LAND	2
11	Cropland and Pasture	21
111	Orchards, Groves, Bush Fruits, Vineyards, and Horticultural	22
12		
13		
14	FOREST LAND	4
15	Heavy Crown Cover (40% and over)	41
	Light Crown Cover (10% to 40%)	42
151	WATER	5
	Streams and Waterways	51
152	Lakes	52
	Reservoirs	53
153	Bays and Estuaries	54
16		
17	NON-FORESTED WETLAND	6
18	Vegetated	61
19		
	BARREN LAND	7
	Beaches	72

SCALE 1:250,000

5 0 5 10

5 0 5 10 15 20

EXPERIMENTAL EDITION

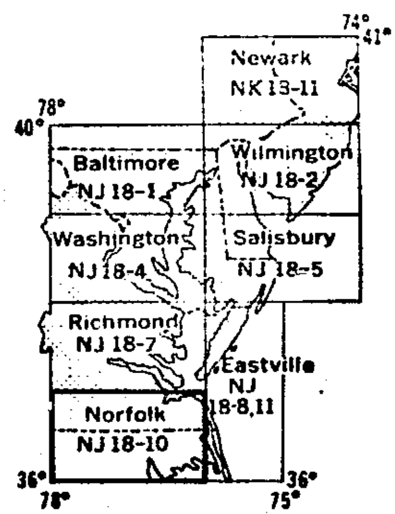
FOLDOUT FRAME 6

45' 30'

LOCATION DIAGRAM

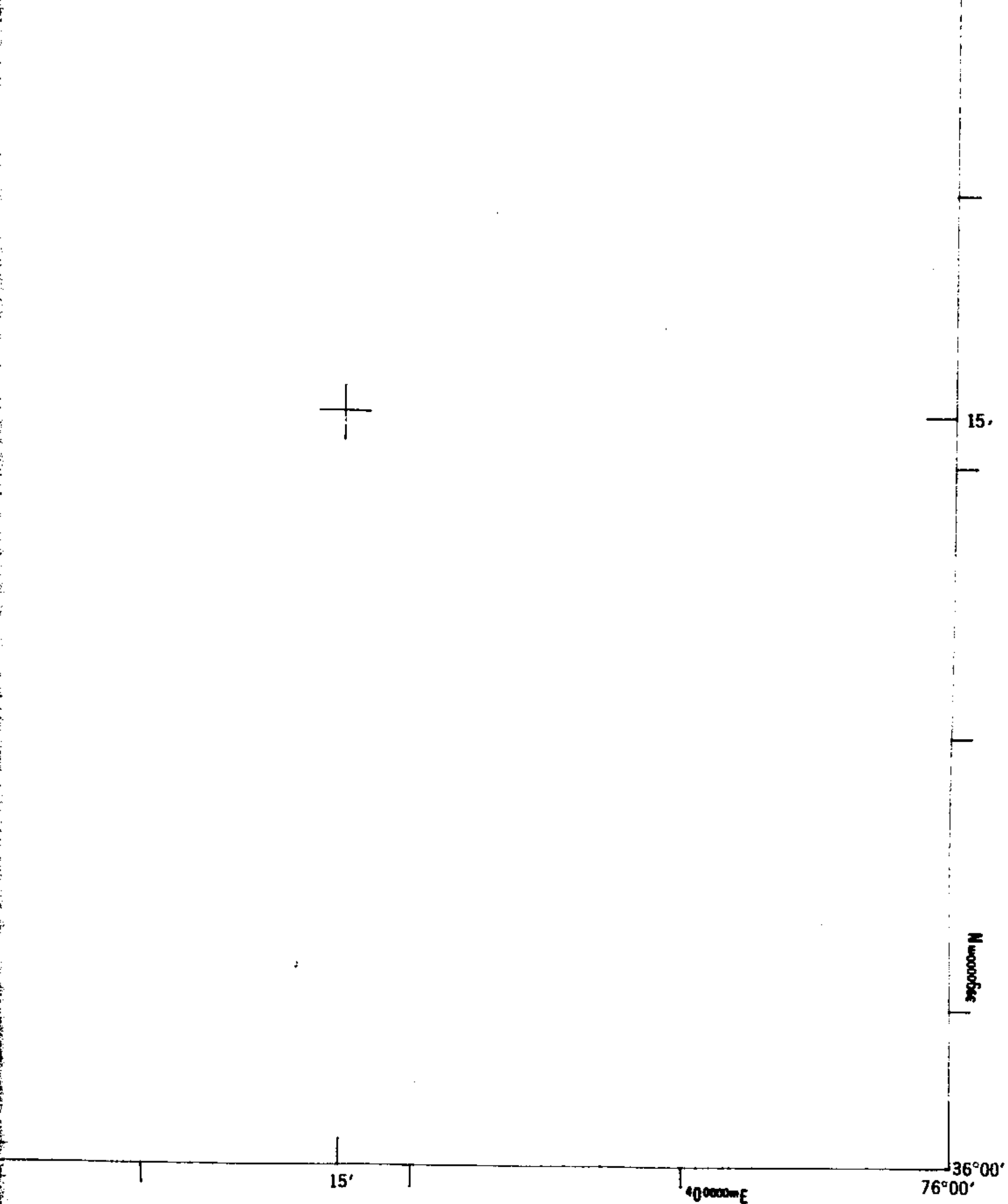
15 20 STATUTE MILES

25 30 KILOMETERS



INDEX TO SHEETS IN THE
CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE

FOLDOUT FRAME 7



NORFOLK, VA., N.C.
ERTS LAND USE
1972

FOLDOUT FRAME 8

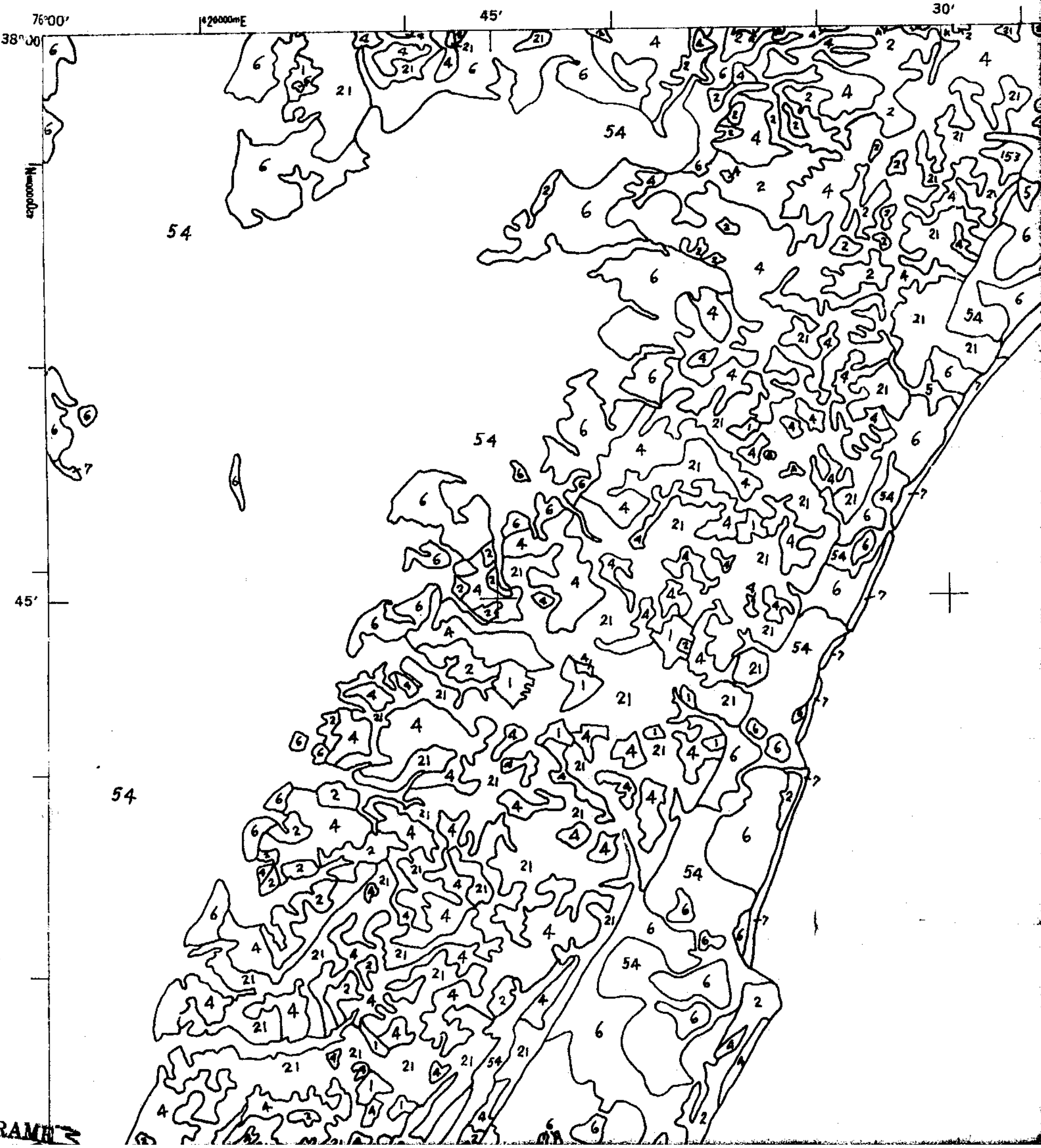
PLATE ?

FOLDOUT FRAME 1

Plat

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

ERTS LAND U



FOLDOUT FRAME 2

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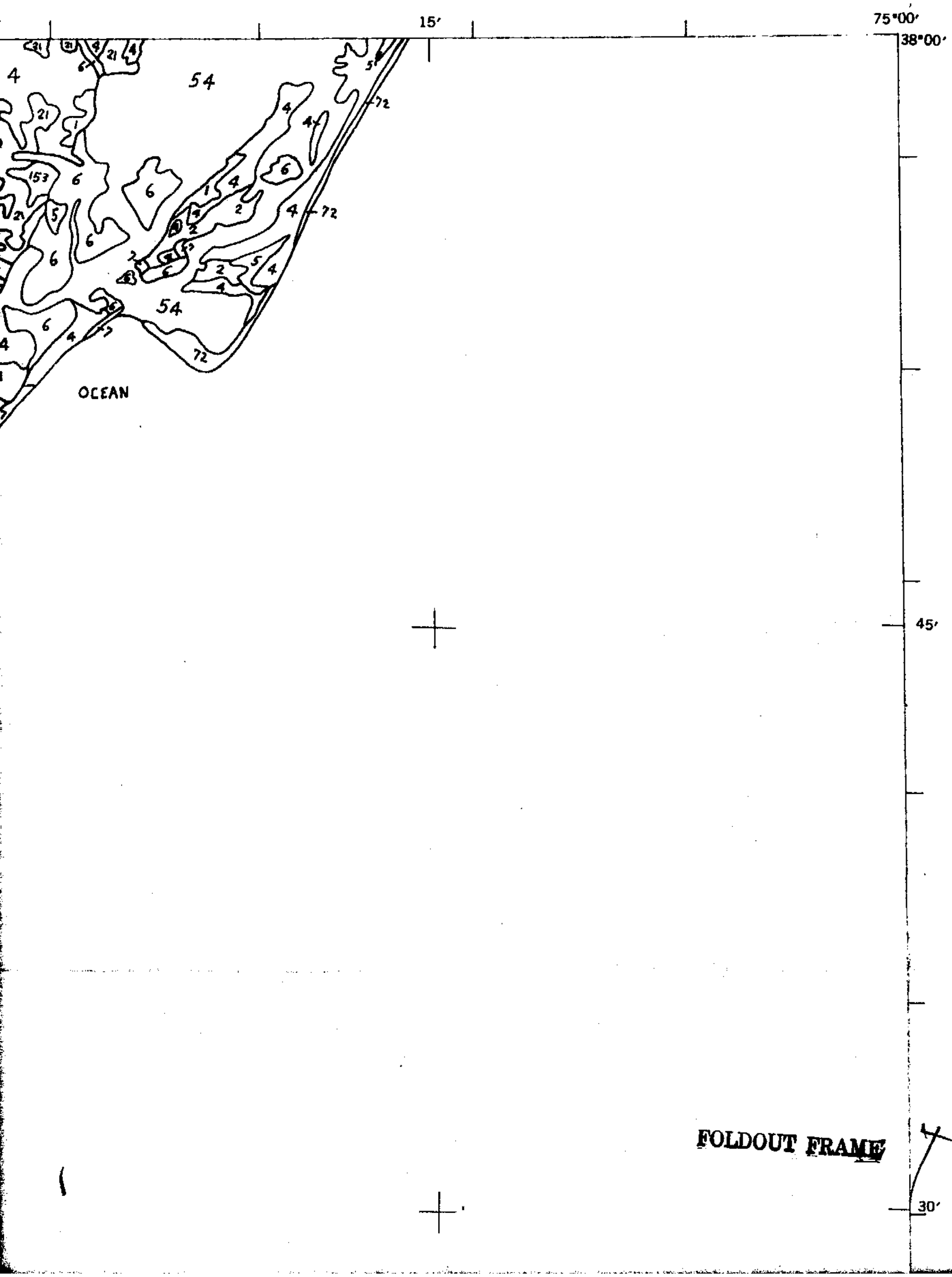
D USE, 1972

N J 18-8, 11
OPEN FILE MAP -- 1974



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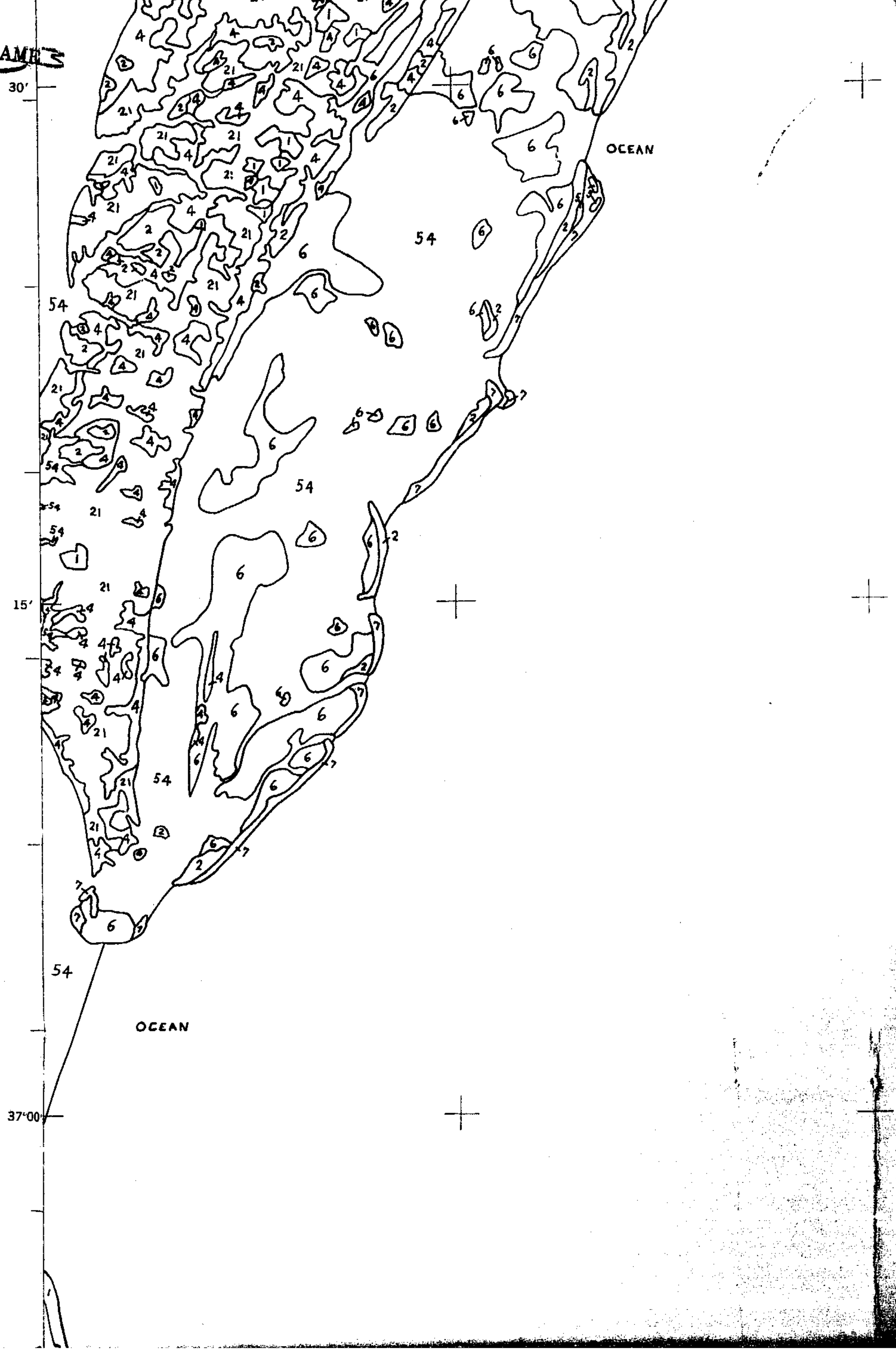

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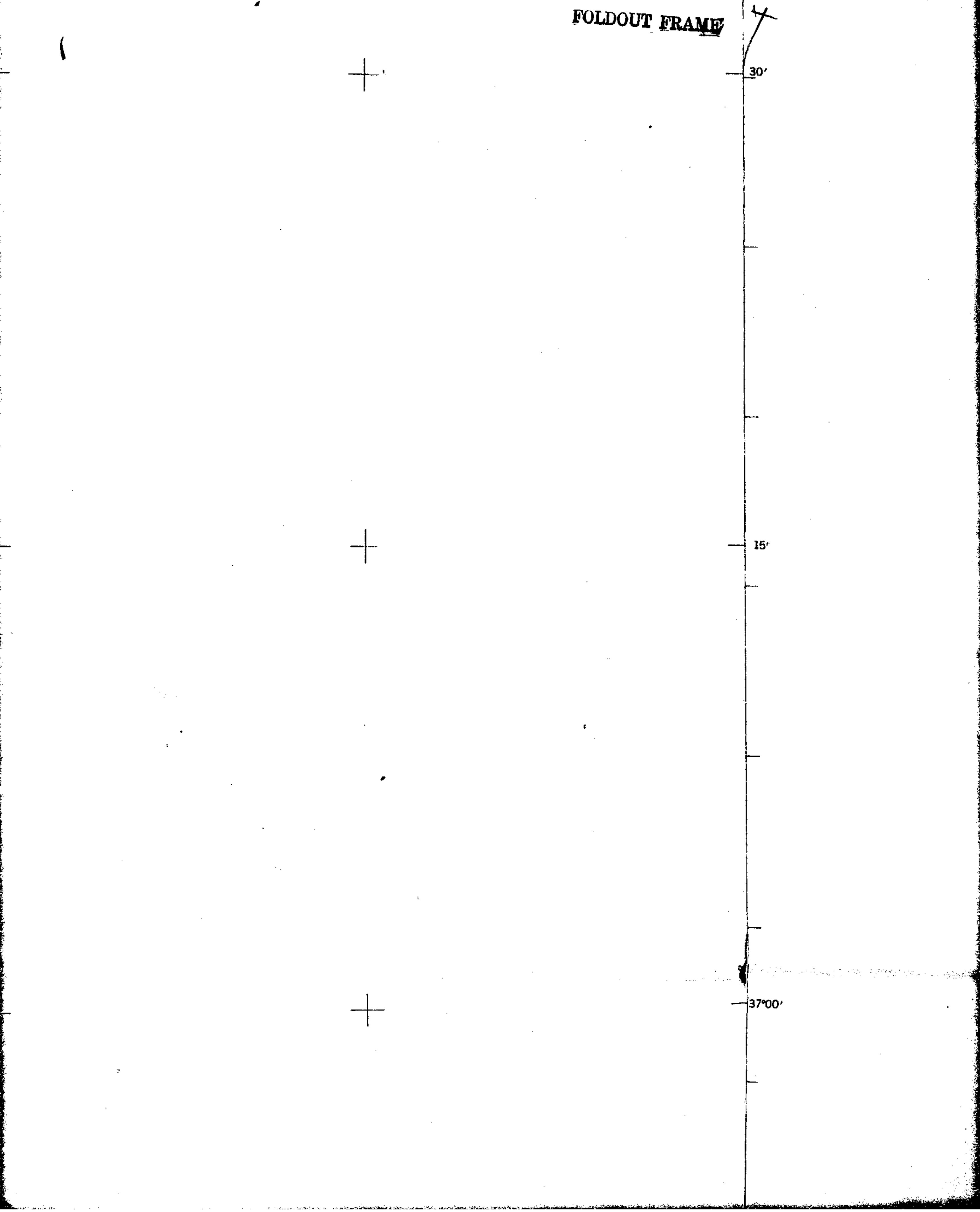

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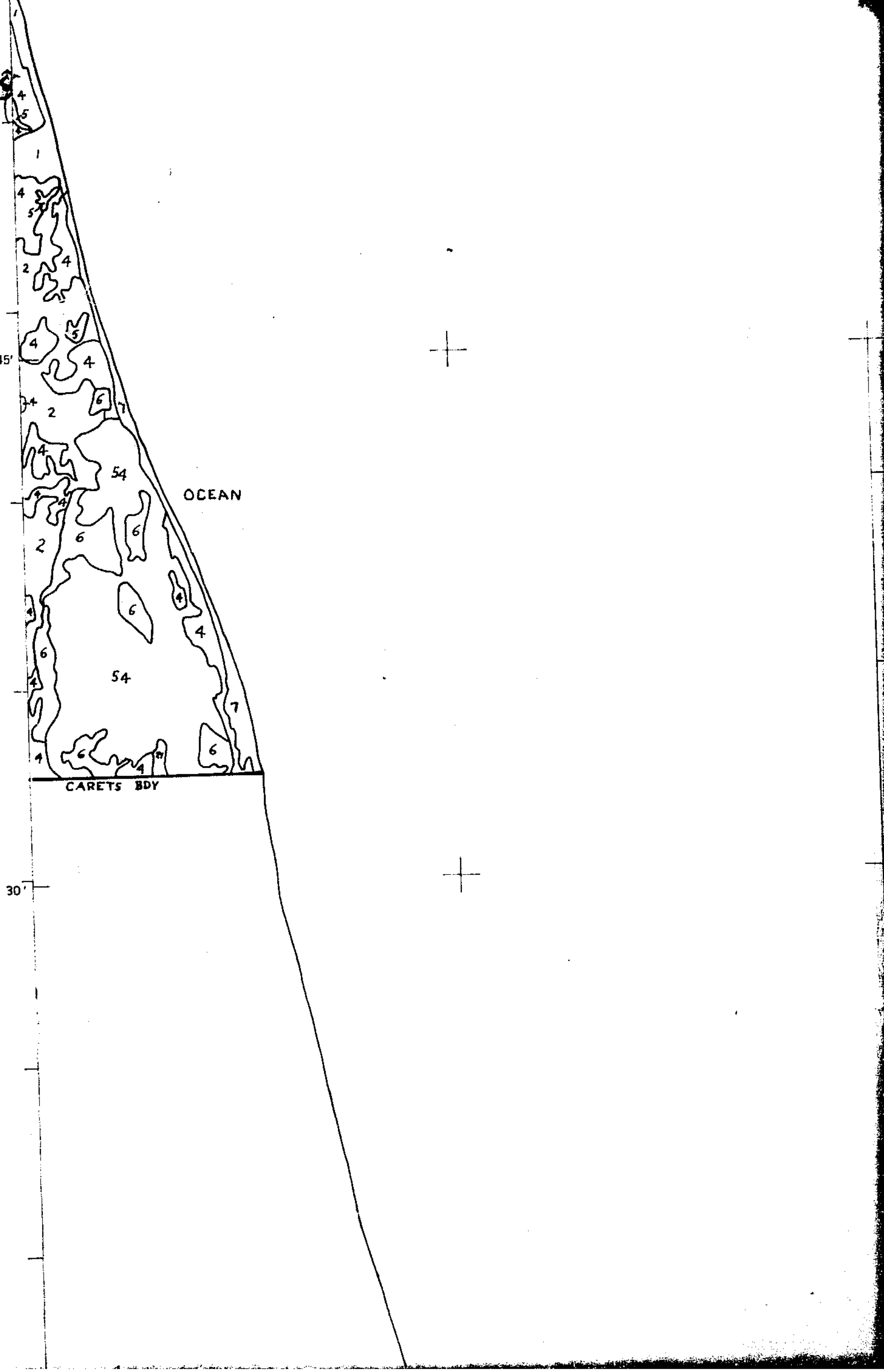
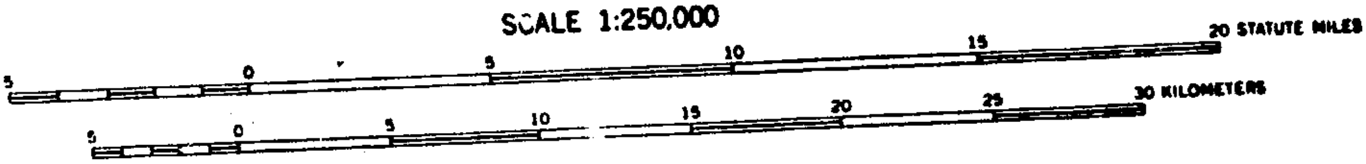


FOLDOUT FRAME 6

36°45′
75°00′
15′

SCALE 1:250,000



This overlay is keyed to the U.S. Geological Survey 1:250,000-scale topographic map.

Land-use data were compiled by the U.S. Geological Survey from 1:250,000-scale Earth Resources Technology Satellite-1 images acquired by the National Aeronautics and Space Administration, 1972.

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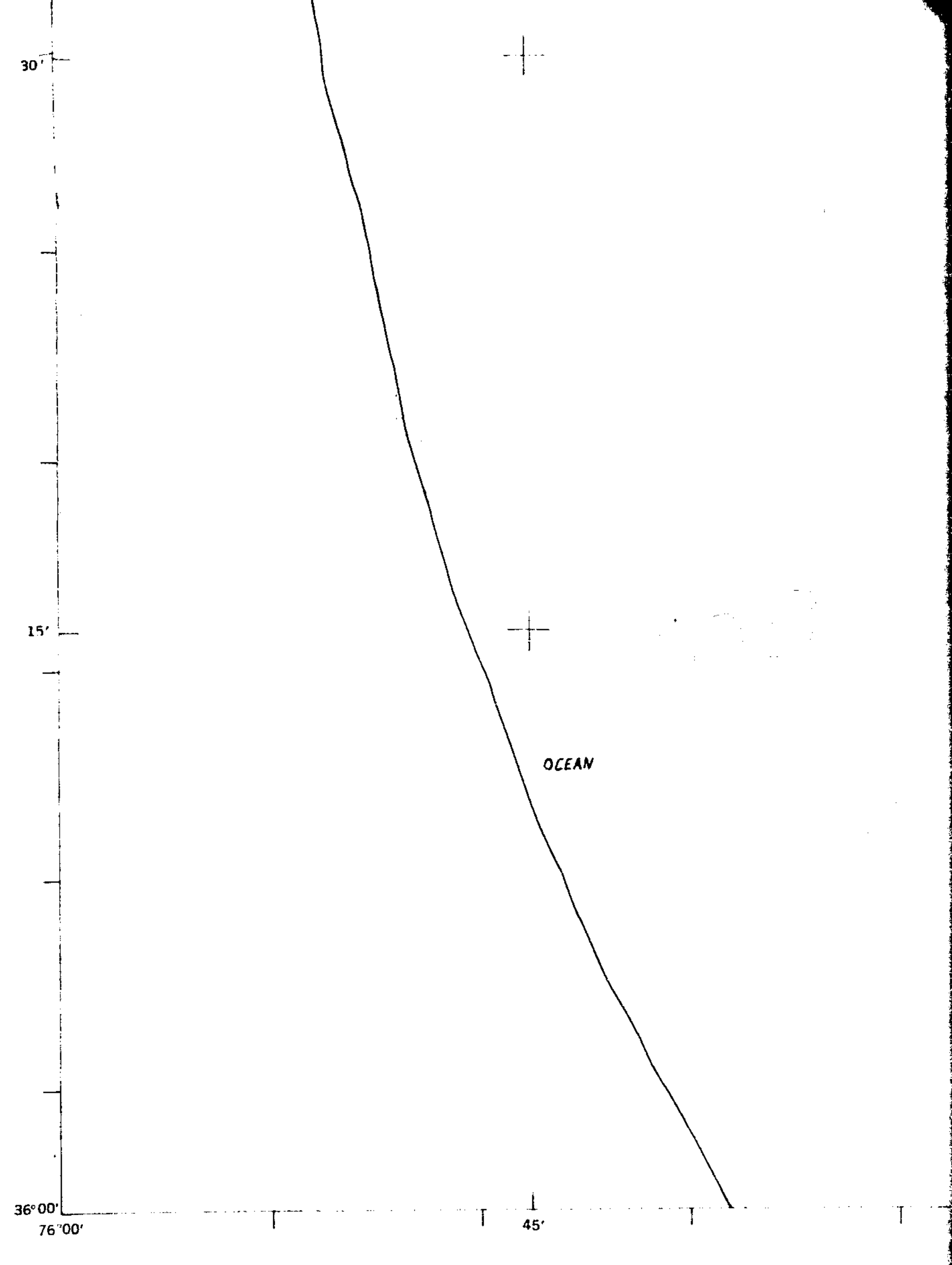
15-minute geographic projection ticks and 10,000 meter ticks: Universal Transverse Mercator, Zone 18, 1927 North American datum.

30′

LAND-USE CLASSIFICATION
ERTS Level I (Levels II and III are shown where identified)

URBAN AND BUILT-UP LAND	1	AGRICULTURAL LAND	2
Residential	11	Cropland and Pasture	21
Single-Family Household Units	111	Orchards, Groves, Bush Fruits, Vineyards, and Horticultural	22
Commercial and Services	12	FOREST LAND	4
Industrial	13	Heavy Crown Cover (40% and over)	41
Extractive	14	Light Crown Cover (10% to 40%)	42
Transportation, Communications, and Utilities	15	WATER	5
Highways, Auto Parking, Bus Terminals, Motor Freight, and Other Facilities	151	Streams and Waterways	51
Railroads and Associated Facilities	152	Lakes	52
Airports	153	Reservoirs	53
Institutional	16	Bays and Estuaries	54
Strip and Clustered Settlement	17	NON-FORESTED WETLAND	6
Mixed	18	Vegetated	61
Open and Other	19	BARREN LAND	7
		Beaches	72

LOCATION DIAGRAM



FOLDOUT FRAME 2

LAND-USE CLASSIFICATION

ERTS Level I (Levels II and III are shown where identified)

URBAN AND BUILT-UP LAND	1	AGRICULTURAL LAND	2
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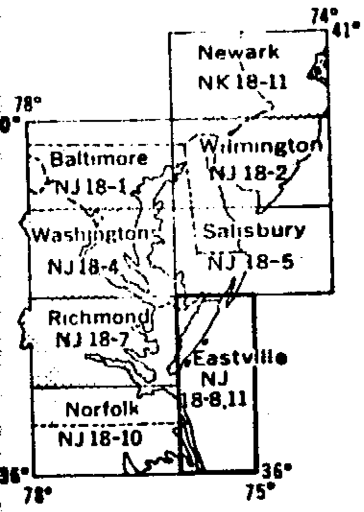
Open and Other	19	BARREN LAND	7
		Beaches	72

LOCATION DIAGRAM



INDEX TO SHEETS IN THE ATLANTIC REGIONAL ECOLOGICAL TEST SITE

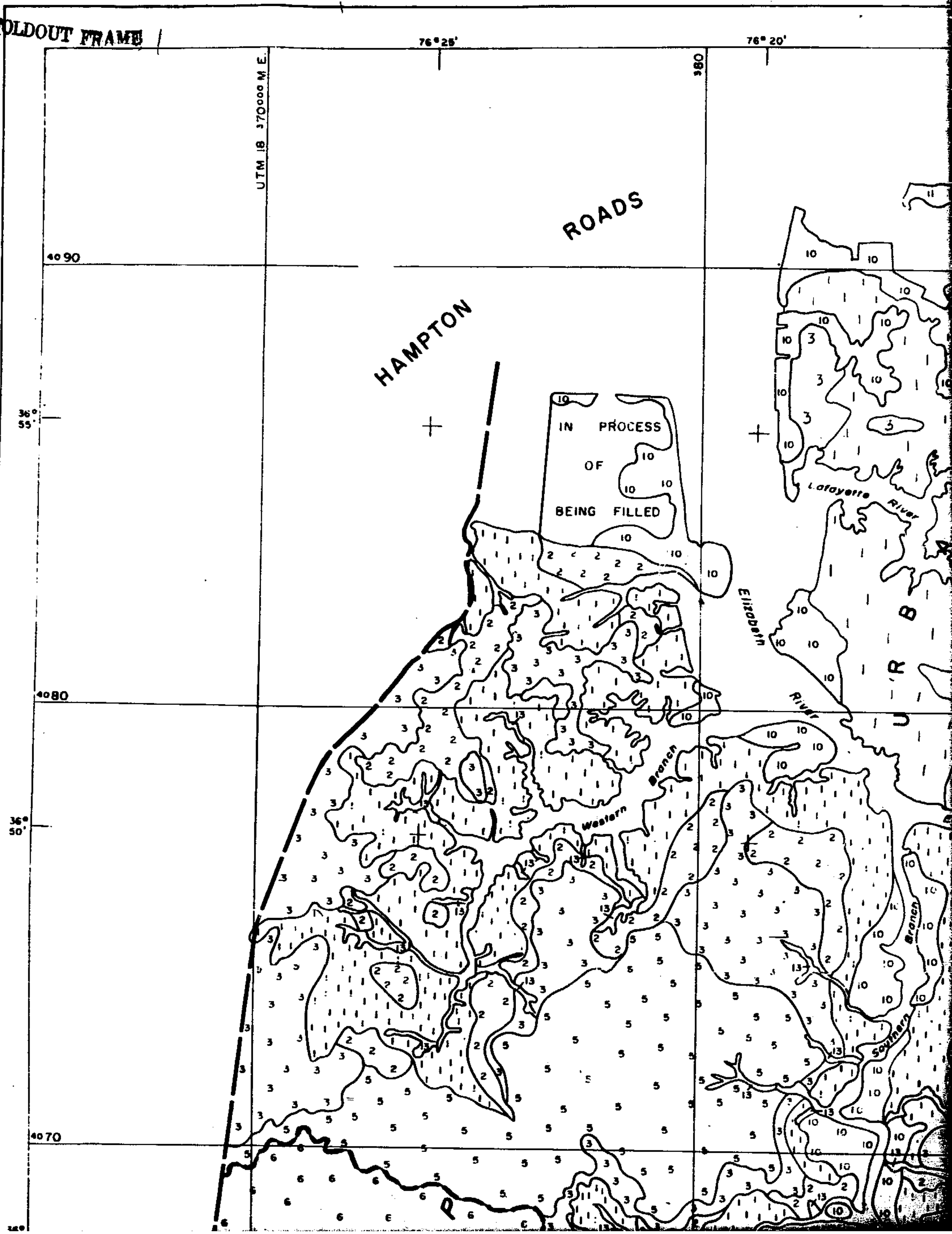
EASTVILLE, VA., N.C., MD.
ERTS LAND USE
1972

MENTAL EDITION

FOLDOUT FRAME 8

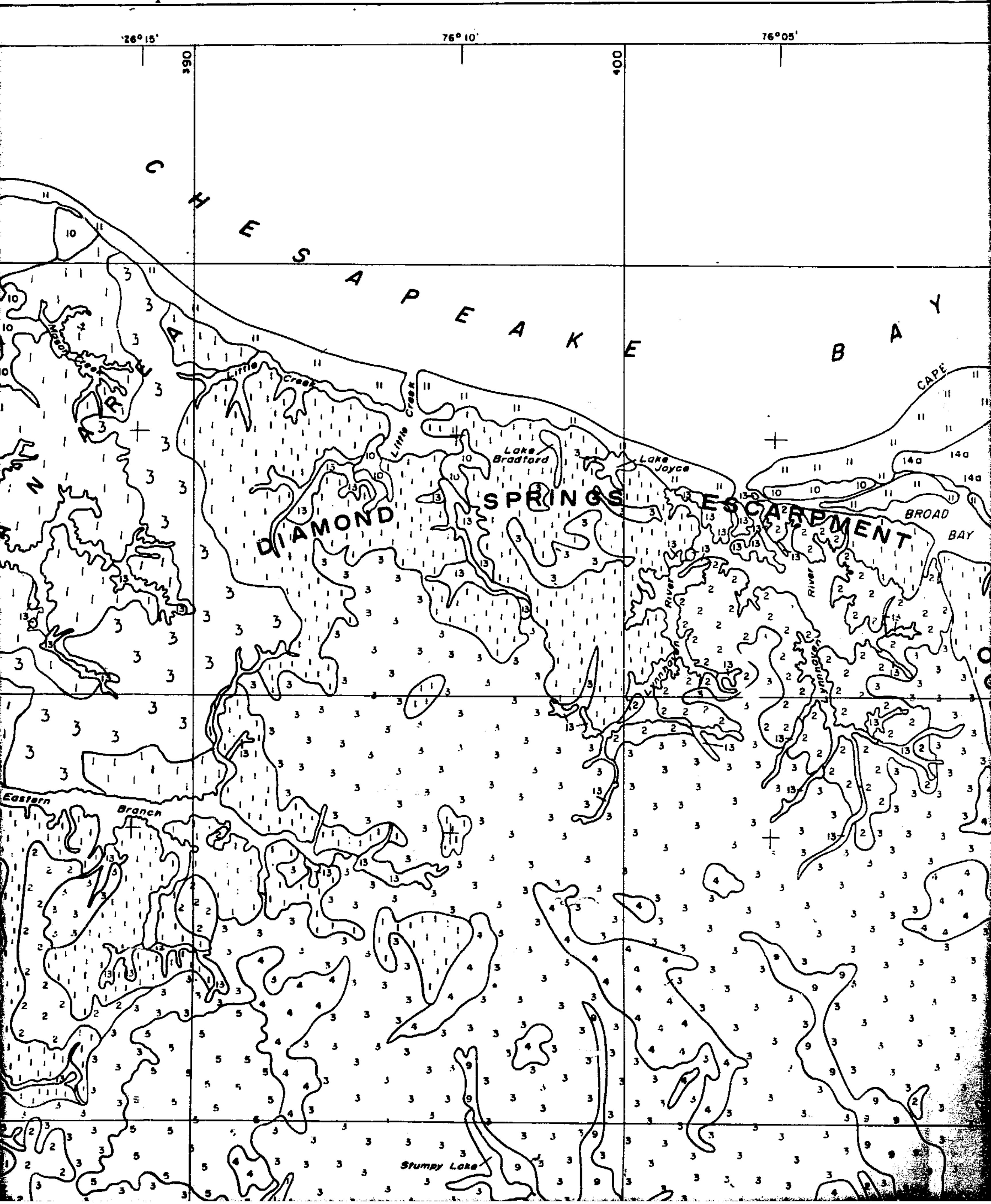
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

FOLDOUT FRAME

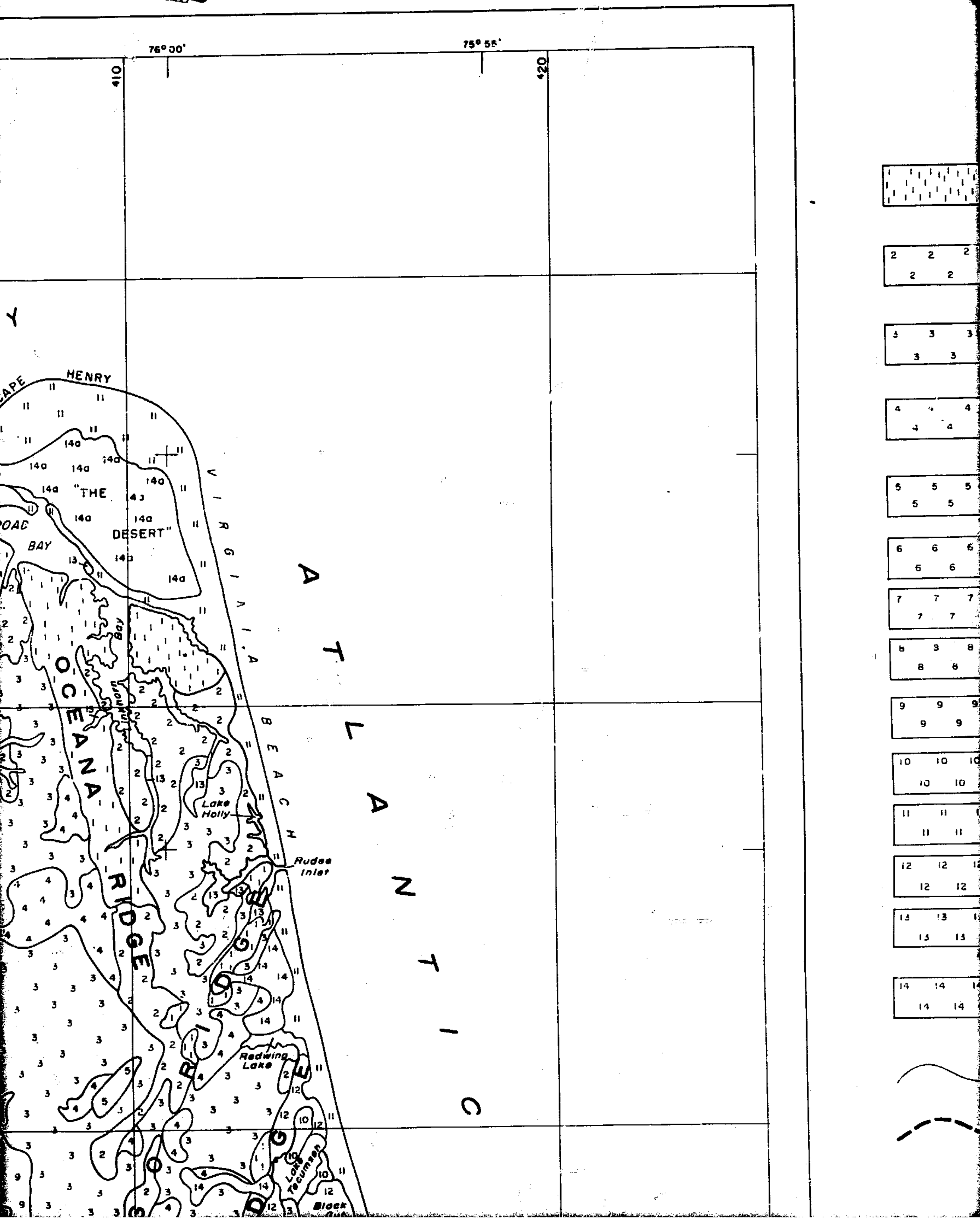


FOLDOUT FRAME 2

Plate 10



DOUT FRAME 3



76° 00'
75° 55'
410
420
HENRY
"THE
DESERT"
BAY
Bay
VIRGINIA
BEACH
ATLANTIC
OCEANA
RIDGE
Lake
Holly
Rudee
Inlet
Redwing
Lake
Lake
Tecumseh
Black

PLATE

FOLDOUT FRAME 4

EXPLANATION

Sand and Gravel; Sand
Former barrier beaches, and in higher areas adjacent to present drainage

Silty Sand
Former barrier beaches, near-shore deposits, and in higher ares adjacent to present drainage

Sandy, Clayey Silt
Former lagoonal and offshore deposits

Silty Clay and Clay
Former lagoonal and offshore deposits
4a Forested wet lands

Deep Plastic Clay over Sand
Former offshore deposits

Deep Mucky Peat of Dismal Swamp

Mucky Peat, shallow over Sand

Mucky Peat, shallow over Silty Clay

Mucky Peat, shallow over Mixed Stream Alluvium, Mostly Clay and Silt

Artificial Fill

Coastal Beaches and Dunes (some stabilized)

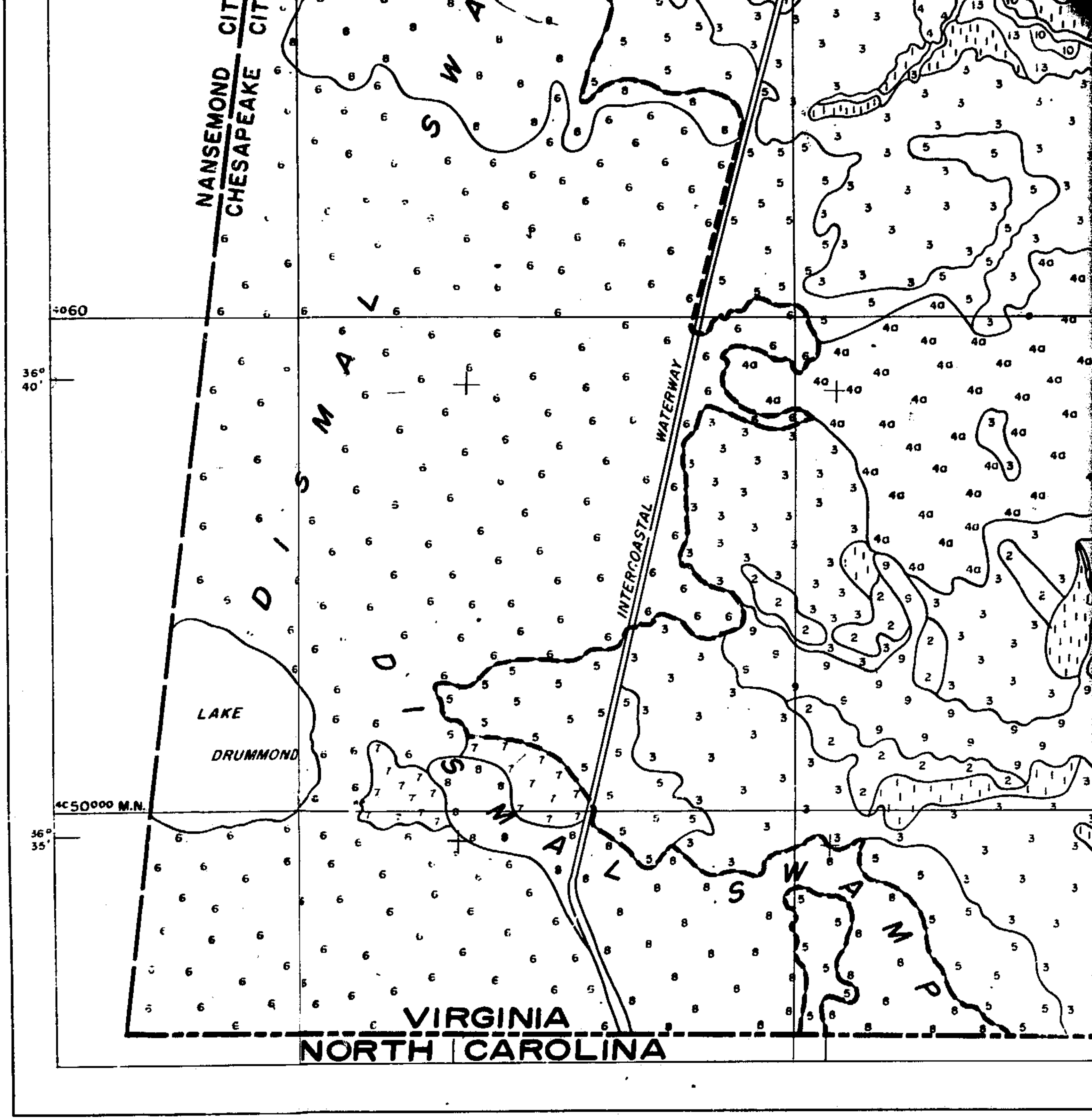
Marsh

Tidal Marsh and Swamp

Fresh to Brackish Swamp
14a Cape Henry Swamp with numerous stabilized dunes "The Desert"

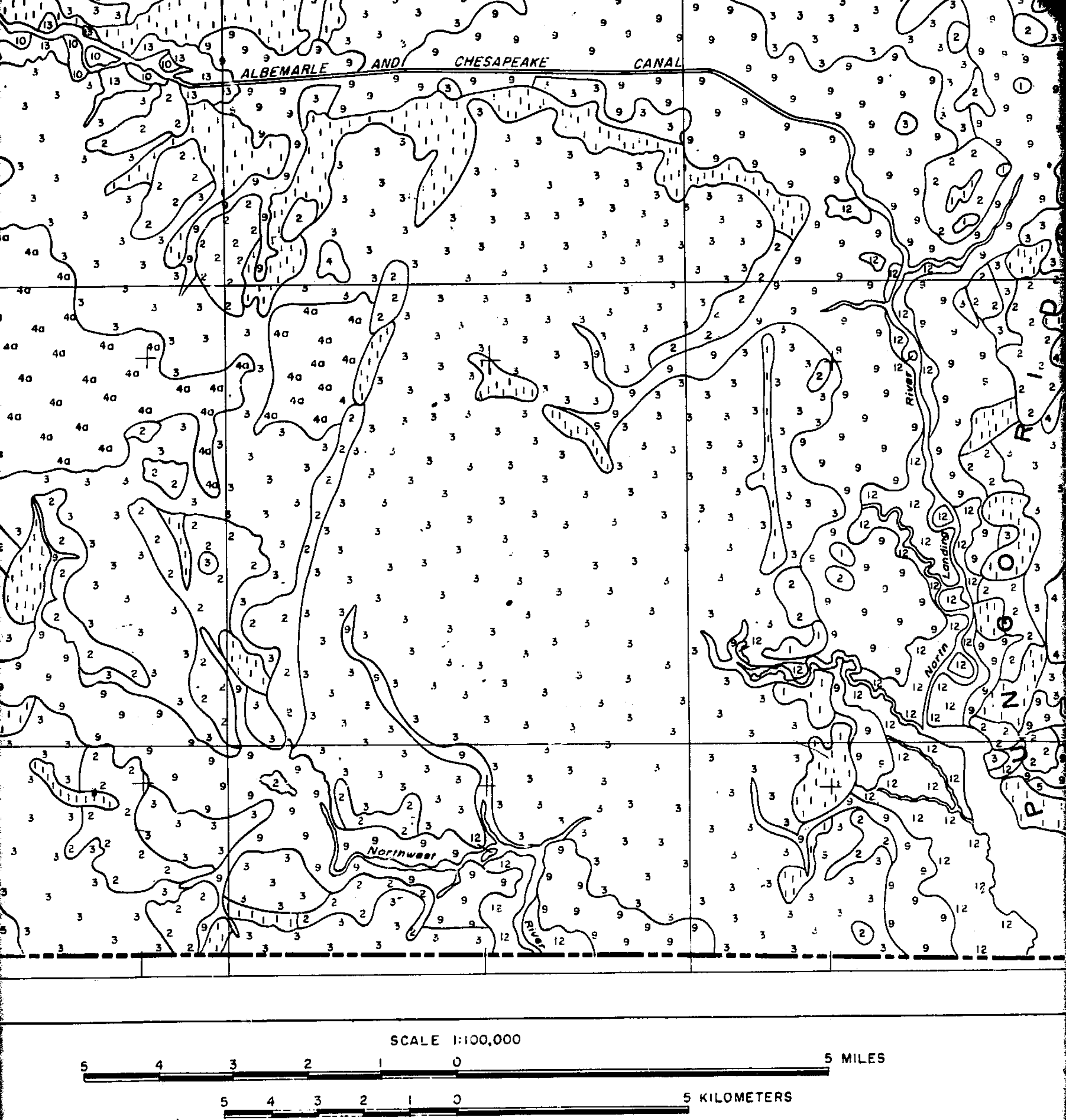
Contact

Boundary of Dismal Swamp



EARTH MATERIALS

FOLDOUT FRAME 5



LS MAP OF THE PORTSMOUTH - NORFOLK AREA, SOUTHEAST V

Compiled by

Sherman K. Neuschel

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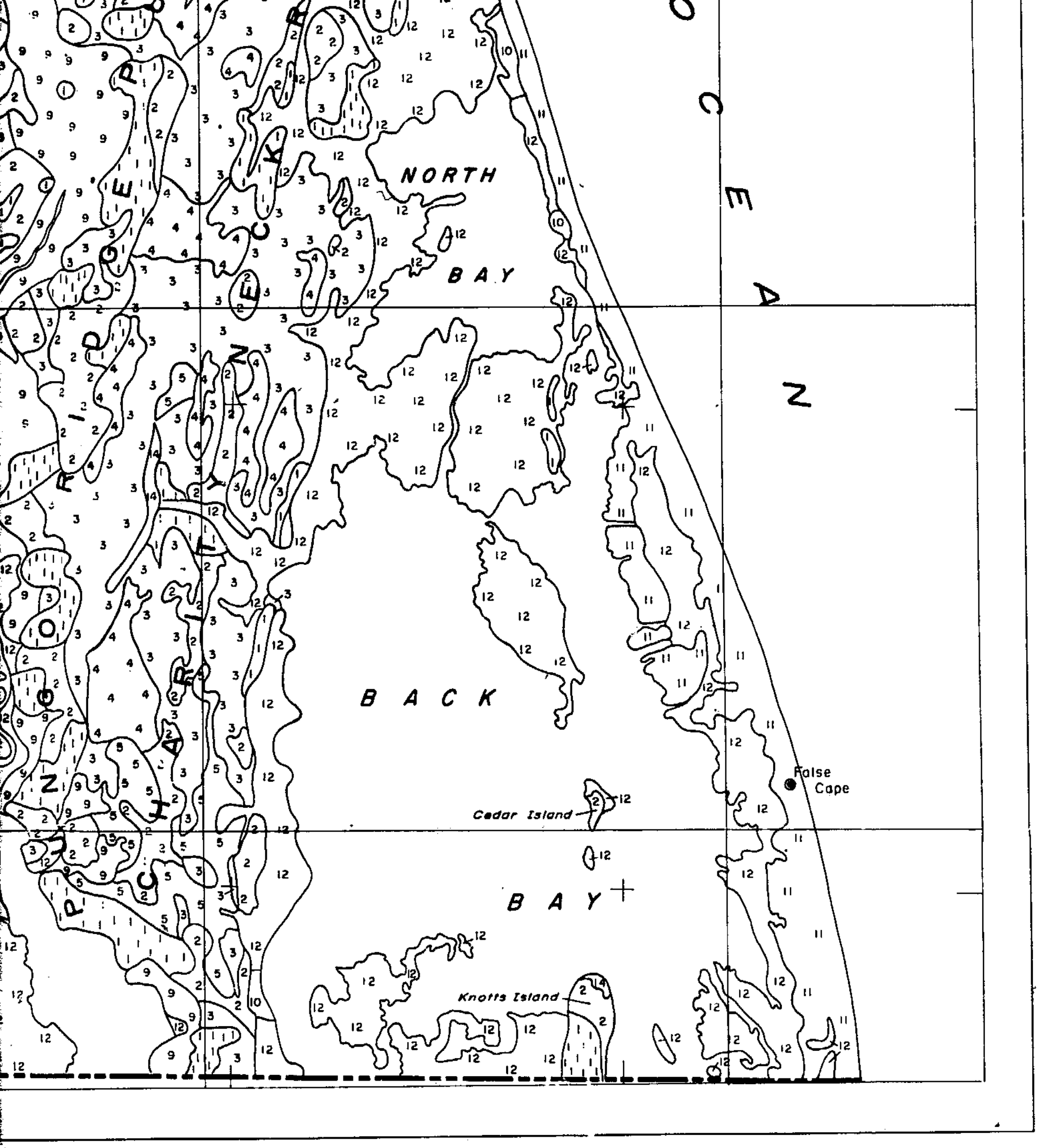

Cocn, N

Henry, E

Ooks, R.

Simmons

U.S. Geological Survey
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This report is preliminary and has not been edited for conformity with Geological Survey standards or nomenclature.

AST VIRGINIA

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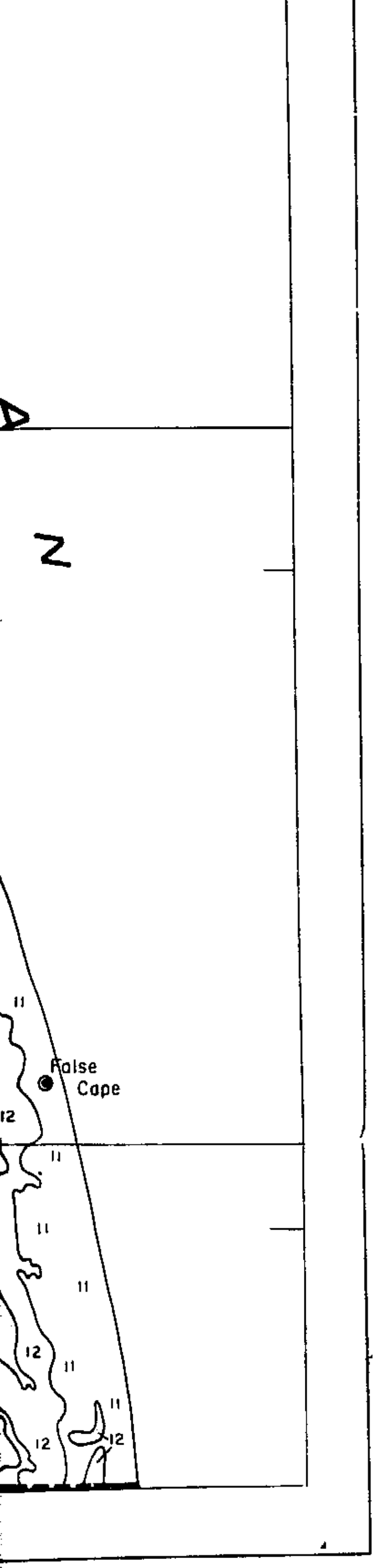

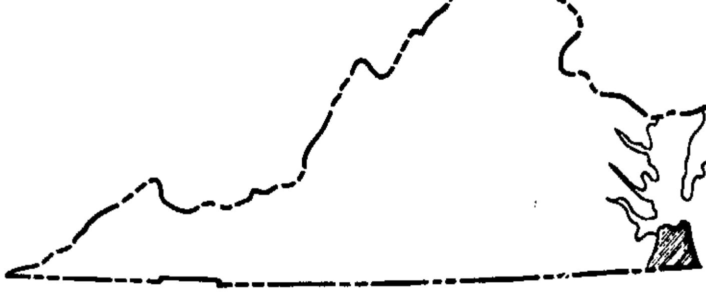

INDEX MAP OF VIRGINIA

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Pla

DESCRIPTION AND PHYSICAL PROPERTIES OF EARTH MATERI

DESCRIPTION OF UNITS

UNIT	DESCRIPTION	TOPOGRAPHIC EXPRESSION AND ORIGIN	PRESENT USE VEGETATION TYPES	DRAINAG CHARACT
1. Sand and Gravel; Sand	Fine to coarse sand in places interbedded with varying amounts of gravel; (pebble size). Thickness: 10' up to 50'; thickest under Charity Neck, Pungo, Oceana Ridges, Diamond Springs Escarpment, and Knotts Island. Thickness: 10'-15' in slopes adjacent to present drainage underlain by 20'-30' of silty clay and sand.	Material makes up parts of former barrier beach complexes and accounts for the N-S trending ridges and the E-W Diamond Springs Escarpment. Ridges rise 10'-15' above adjacent lower areas. Material in slopes adjacent to present drainage are stream overflow deposits.	Virtually all urbanized, industrial, and residential with varying degrees of intensity. In southern half of the study area the unit is in intensive agriculture-multiple crops throughout year.	Excelle well dr Slight need fo ficial Depth t ally hi table.
2. Silty Sand	Fine sand and silty sand. Thickness: 10' to 50'. Thickest under Charity Neck, Pungo, and Oceana Ridges, and Diamond Springs Escarpment.	Same as above	Same as above except a few areas still wooded.	Moderat drained areas r drainag for cul Depth t ally hi table 1
3. Sandy, Clayey Silt	Fine sandy clayey silt, to depth of 5' underlain by sticky clayey sand. Thickness: 20'-40'.	Most extensive unit in the study area and occupies broad extremely flat areas with elevations ranging from 10'-20' above sea level. Material is former lagoonal and offshore fine marine deposits.	Urbanized in north and in Norfolk and Portsmouth. Remainder more than 90% in cultivation. Remaining scattered areas undrained and wooded.	Fair t Most o requir draina and in closely lateral ditches land c able. Season water surfac
4. Silty Clay and Clay	Plastic silty clay and clay with some layers of sticky clayey sand. Thickness: 20'-40'.	Low lying poorly drained sites developed from fine grained offshore marine deposits.	As recently as the 1940's all areas were wooded. Now about 80% of unit has been reclaimed for agriculture. Wooded areas remaining support dense growths of black tupelo, loblolly pine, yellow poplar, sweetgum, red maple and willow oak. Thick underbrush of cane or reeds and briers.	Very p Requir draina and in closel latera ditche land c able. high w at sur Before much o perman

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Plate 11

...RTIES OF EARTH MATERIALS IN THE PORTSMOUTH-NORFOLK AREA, SOUTHEAST VIRGINIA

Compiled by Sherman K. Neusche...
U. S. Geological Survey, 1975

FEATURES AFFECTING AGRICULTURE AND ENGINEERING WORK (a)

...ES	DRAINAGE CHARACTERISTICS	SOIL TYPES AND AGRICULTURAL ADAPTABILITY	ADAPTABILITY TO EARTH WORK IN WET PERIODS	FEASIBILITY FOR USE AS TOP SOIL	FEASIBILITY AS SOURCE OF CONSTRUCTION MATERIALS (b)	FEASIBI... FOUNDAT... (b) (...
...urbanized, ...d residential ...egrees of ...southern ...dy area ... intensive ...ltiple crops ...r.	Excellently to well drained. Slight to no need for artificial drainage. Depth to seasonally high water table. 2-4½'	Friable fine sandy loams. Excellent--Best and most productive agricultural lands in study area.	Good to Fair	High	High. Ridges of this unit are excellent source of gravel and sand. Good base course material, and source for aggregate when screened.	Very h...
...xcept a few ...led.	Moderately well drained. Some areas require drainage ditches for cultivation. Depth to seasonally high water table 1½'-2½'.	Fine sandy and silty loams. Very high	Fair to Poor	High to Medium	High to Medium. Some of well sorted sands suitable for fill, and construction material.	Hig...
...th and in ...smouth. ...han 90% in ...aining scatt- ...ined and	Fair to poor. Most of area requires deep drainage channels and intensive closely spaced lateral drainage ditches to make land cultivatable. Seasonally high water table at surface.	Fine silty loam with plastic, sticky clay subsoil. Very high to good if properly drained and limed. Fertilizer requirement high.	Not Adaptable	Medium to Low	Medium to Low. Some clayey material can be used for borrow.	Medium
...e 1940's all ... Now about ...een reclaimed ... Wooded areas ... dense ...tupelo, ...llow poplar, ...le and willow ...brush of cane ...ers.	Very poor. Requires deep drainage canals and intensive closely-spaced lateral drainage ditches to make land cultivatable. Seasonally high water table at surface. Before drainage much of unit permanently wet.	Black, mucky fine silt loam with subsoil of sticky, plastic clay. High to medium adaptability for agriculture if adequately drained and limed. Fertilizer requirement high.	Not Adaptable	Low	Medium to Low. Some clays can be used for borrow.	Very p...

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SMOUTH-NORFOLK AREA, SOUTHEAST VIRGINIA

AFFECTING AGRICULTURE AND ENGINEERING WORK (a)

Compiled by Sherman K. Neuschel
U. S. Geological Survey, 1975

SOIL TYPES AND AGRICULTURAL ADAPTABILITY	ADAPTABILITY TO EARTH WORK IN WET PERIODS	FEASIBILITY FOR USE AS TOP SOIL	FEASIBILITY AS SOURCE OF CONSTRUCTION MATERIALS (b)	FEASIBILITY FOR FOUNDATION MATERIAL (b) (c)
ble fine sandy s. llent--Best and productive cultural lands tudy area.	Good to Fair	High	High. Ridges of this unit are excellent source of gravel and sand. Good base course material, and source for aggregate when screened.	Very high
e sandy and ty loams. y high	Fair to Poor	High to Medium	High to Medium. Some of well sorted sands suitable for fill, and construction material.	High
silty loam with tic, sticky clay oil. high to good roperly drained limed. ilizer require- high.	Not Adaptable	Medium to Low	Medium to Low. Some clayey material can be used for borrow.	Medium to Low
, mucky fine loam with sub- of sticky, tic clay. to medium tability for culture if ade- ly drained and . Fertilizer rement high.	Not Adaptable	Low	Medium to Low. Some clays can be used for borrow.	Very poor to low.
mucky fine				

FOLDOUT FRAME 6

and Clay Forested wet lands	by some considered an extension of Dismal Swamp known locally as the "Green Sea")	area east of Dismal Swamp and south of Albermarle and Chesapeake Canal. Developed from fine-grained, offshore marine deposits.	either wooded with same species as Unit 4 above. Wh timbered or burned over comprises dense growth of briers, cane, myrtle, and honeysuckle.
5. Deep Plastic Clay over Sand	4' plastic, sticky fine sandy clay over 4'-6' loose sticky sand, over 20' or more of silty clay.	Extremely flat areas 15'-20' in elevation bordering or near Dismal Swamp. A few small low areas 5'-10' in elevation between sand ridges west of Back Bay. Former offshore marine and lagoonal deposits.	Formerly swampy and wooded. Now nearly all drained and reclaimed. Some areas urbanized, others in agriculture.
6. Deep Mucky Peat of Dismal Swamp	3'-15' mucky peat underlain by 20'-30' silty clay and loose sticky sand. Peat ranges from a true peat in which plant species are easily recognized to a muck in which it is difficult to determine plant remains. Contains many partially decomposed logs and stumps.	Extremely flat area in western part with elevation 15'-20' above sea level.	Densely wooded except for burned over area in north. Trees are mainly red maple ash, swamp oak, cypress, pine, poplar, beech, and varieties of gums. Contain a thick undergrowth of mos sedges, ferns, cane, honey suckle, myrtle, alder, hol and gallberry. Forest provides habitat for a lar variety of wildlife.
7. Mucky Peat, shallow over sand	0"-6" partly decomposed organic matter, over 1'-2' mucky peat; over 3' loose fine sand; over 20'-30' silty clay and sticky sand.	Flat areas bordering Dismal Swamp.	Formerly wooded but areas of this unit being reclaim
8. Mucky Peat shallow over silty clay	Similar to deep mucky peat of Dismal Swamp except that peat is only 1'-2' thick.	Flat areas bordering Dismal Swamp	Wooded with species like re of Dismal Swamp listed abo for Unit 6.
9. Mucky Peat, shallow over mixed stream Alluvium, mostly clay and silt.	1'-2' mucky peat over mixed stream alluvium mostly clay and silt with some sand. Alluvium in two major drainage ways, the Northwest and North Landing Rivers extends to a depth of about 50' (50' below sea level) at the Virginia-North Carolina border where the streams enter Currituck Sound south of the mapped area.	Flat alluvial surfaces in the two main drainageways and their tributaries. Streams descend from an elevation of 5'-10' to sea level where they enter Currituck Sound.	Forested wet lands contai an assemblege similar to Dismal Swamp described in 6 above.
10. Artificial Fill	Areas filled with waste rubble, and dredged material from ship channels off Hampton Roads and in the Elizabeth River to create ship berthing and warehouse facilities along Elizabeth River and to expand facilities on Norfolk-Portsmouth waterfront.	Filled peat areas, former streams and tidal marshes.	Commercial-transportation docking, ship handling & warehouse facilities.
11. Coastal	Greyish-yellow incoherent	The coastal beach is a	Mostly used for recreatio

eeds and briers.	at surface. Before drainage much of unit permanently wet.	requirement high.			
mall area beginning to claimed - otherwise r wooded with same es as Unit 4 above. Where red or burned over ises dense growth of s, cane, myrtle, and suckle.	Exceedingly poor. Intensive artificial drainage needed to reclaim. Under water except in long dry periods.	Black, mucky fine silt loam containing much humus. High to medium adaptability for agriculture if adequately drained and limed to reduce high acidity.	Not Adaptable	Low to very low because of high acidity. Medium feasibility when drained and limed.	Low to very low. Some clays might b used for borrow.
rly swampy and wooded. early all drained and imed. Some areas ized, others in agri-re.	Very poor. Requires deep drainage canals and closely spaced drainage ditches. Areas near Dismal Swamp were very difficult to drain. Seasonally high water table at surface.	Black, very fine silty clay loam with abundant humus. Subsoil is plastic, sticky, heavy clay loam. Very high to high when properly drained and limed.	Not Adaptable	Medium to Low	Low to very low. Some clays might used for borrow.
ly wooded except for ed over area in north. s are mainly red maple, swamp oak, cypress, , poplar, beech, and eties of gums. Contains ick undergrowth of moss, es, ferns, cane, honey-le, myrtle, alder, holly, gallberry. Forest ides habitat for a large ety of wildlife.	Very Poor Seasonally high water table at surface. Except for prolonged dry periods much of Dismal Swamp has standing water.	Black, fine mucky organic soils extremely acid. Very low to nil for agriculture though could be drained with difficulty.	Not Adaptable	Low to very Low.	Very low to nil.
erly wooded but areas his unit being reclaimed.	Very Poor seasonally high water table 0'. Standing water at surface most of time until drained.	Black, fine mucky organic soils extremely acid. Low adaptability for agriculture after extensive artificial drainage.	Not Adaptable	Low to very low because of high acidity.	Very low to nil
with species like rest ismal Swamp listed above Unit 6.	Same as above. Will be extremely difficult to drain.	Black fine extremely acid mucky organic soils. Very low to nil for agriculture.	Not Adaptable	Low to very low because of high acidity.	Very low to nil.
sted wet lands containing ssemblege similar to al Swamp described in ve.	Standing water at surface most of time.	Black mucky organic peat soil mixed with stream alluvium in subsurface. Not adaptable for agriculture.	Not Adaptable	Low to very low.	Not generally us though some allu ium dredged for making new land.
ercial-transportation ng, ship handling and ouse facilities.	Well drained	Mixed alluvium and earth and rubble fill. No natural soil profile developed. No agricultural use.	Not Applicable once made land completed and built up.	Not Applicable	Not Applicable

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n to medium ptability for culture if adequately drained and d. Fertilizer uirement high.			used for borrow.	
k, mucky fine loam containing humus. to medium ptability for culture if uately drained limed to reduce acidity.	Not Adaptable	Low to very low because of high acidity. Medium feasibility when drained and limed.	Low to very low. Some clays might be used for borrow.	Very Low.
k, very fine y clay loam with dant humus. oil is plastic, ky, heavy clay . high to when properly ned and limed.	Not Adaptable	Medium to Low	Low to very low. Some clays might be used for borrow.	Very Low.
ck, fine mucky anic soils remely acid. y low to nil agriculture ugh could be ined with fficulty.	Not Adaptable	Low to very Low.	Very low to nil.	Very low to nil.
ck, fine mucky anic soils remely acid. adaptability agriculture after ensive artificial inage.	Not Adaptable	Low to very low because of high acidity.	Very low to nil.	Very low to nil.
ck fine extremely acid mucky ganic soils. ry low to nil for riculture.	Not Adaptable	Low to very low because of high acidity.	Very low to nil.	Very low to nil.
k mucky organic soil mixed stream alluvium subsurface. adaptable agriculture.	Not Adaptable	Low to very low.	Not generally usable though some alluvium dredged for making new land.	Very Low.
d alluvium and h and rubble No natural	Not Applicable once made land	Not Applicable	Not Applicable	High to Medium Depending on [illegible]

	wind-blown dunes and stabilized dunes. All sand of dunes contains appreciable silt. Dunes stabilized for a long time have developed a feeble soil profile with a loamy subsoil.	one mile. Dunes are of two types: (1) Those active and subjected to wind action and, (2) those stabilized by vegetation. Average elevation of the dunes is about 35' but they vary from a few feet to 100' on Cape Henry and in some places both extremes are found within a few hundred feet. South of Virginia Beach in vicinity of False Cape are many dunes 40'-50' high.	coarse bunch Beaches and d being preserv incursion of on land and i and Back Bays
12. Marsh Deposits	Silty clay with varying quantities of organic matter in various stages of decomposition. Sandy in a few places. Some areas have 3"-6" of sedge peat on surface. Inundated by fresh to slightly brackish water.	Low inundated areas in North and Back Bays, and along the North Landing and Northwest Rivers.	Recreation: Scant grazin consists of grass, and r
13. Tidal Marsh and Swamp Deposits	Gray to dark gray silty clay, muds, and organic matter in various stages of decomposition. Inundated by salt water tides.	Inundated areas bordering Lynnhaven Bay, Little Creek, and the Elizabeth River.	Not used for Tidal marsh cattle. Vege of dense gro grasses and more extensi now filled i and wharehou
14. Fresh to Brackish Swamp Deposits	Silt and sandy alluvium	Three small fresh to slightly brackish swamps along east and south flowing drainage ways feeding North and Back Bays. Areas more extensive in past but now filled in.	Not used. Vegetation c maple, swamp poplar, and
14a. Cape Henry Swamp Deposits	Many narrow strips of stabilized dune sands, in many places less than 100' wide in large area of swamp. Thin soil profile developed on dunes. 3"-4" organic matter overlies white sand surface soil. Subsoil is loamy sand. Substratum is grayish-yellow loose sand. Much of swamp area has 2'-3' of peat at surface.	Dunes as much as 35'-40' high are crescentic in shape paralleling beach lines on Cape Henry and possibly represent old beach lines or sand bars.	Recreation Seashore St Vegetation: pine, swamp

(a) Agricultural and engineering adaptability based on agricultural and engineering data from soils reports of Norfolk and Princess Anne Counties, Virginia (References 2 and 4) which cover entire area of study.

(b) Ratings are for general guidance only as units vary in composition. Specific feasibility should be based on field surveys and testing.

(c) Ratings are for subgrade and subbases.

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coarse bunch grass. Beaches and dunes are being preserved to prevent incursion of storm waters on land and into North and Back Bays.	frequently inundated and drains slowly.			on land and into North and Back Bays.	build up Beach becau presence of material wh quickly rem wave action on beach. M dunes are b preserved t prevent inc of storm wa from Atlant into North Back Bays.
Recreation: wild fowl hunting Scant grazing. Vegetation consists of cattails, celery grass, and reeds.	Wet lands	Organic & peaty soils. No agriculture use.	Not Adaptable	Not used	Not feas
Not used for any purpose. Tidal marsh will not support cattle. Vegetation consists of dense growth of coarse grasses and reeds. Formerly more extensive--many areas now filled in for docking and wharehouse facilities.	Wet lands	Thin organic soils. No agricultural use.	Not Adaptable	Not used	Not feasi
Not used. Vegetation consists of red maple, swamp oak, ash, poplar, and sweetgum.	Wet lands	A few inches of dark organic soil over stream alluvium. No agricultural use.	Not Adaptable	Not used	Not feasi
Recreation Seashore State Park Vegetation: cypress, loblolly pine, swamp oak, poplar.	Dune areas well drained	Few inches of organic matter on dunes, No agricultural use	Accessable dunes, good adaptability.	Not used	Medium to Dune sands be used fo but not su build up V Beach beca fines in

Virginia (Portsmouth - Norfo
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REFERENCES

1. Coch, Nicholas K., 1965. Post-Miocene stratigraphy and morphology, inner Coastal Plain, southeastern Virginia: U. S. Office Naval Research, Geography Branch Tech. Rept. 6 (Contract NONR 609 (40), Taks Order NR 388-064), 97 p.

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4. Simmons, C. S., and Shulkcom, Edw survey of Princess Anne County, Dept. Agr. Div. of Soil Survey, no. 3, 57 p.

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		on land and into North and Back Bays.	build up Virginia Beach because of presence of silty material which is quickly removed by wave action if put on beach. Moreover, dunes are being preserved to prevent incursion of storm waters from Atlantic Ocean into North and Back Bays.	
rganic & peaty oils. o agriculture se.	Not Adaptable	Not used	Not feasible	Not feasible
hin organic soils. o agricultural se.	Not Adaptable	Not used	Not feasible	Not feasible
few inches of rk organic soil er stream alluvium, agricultural use.	Not Adaptable	Not used	Not feasible	Not feasible
ew inches of rganic matter on unes, o agricultural use	Accessable dunes, good adaptability.	Not used	Medium to low. Dune sands could be used for fill but not suited to build up Virginia Beach because of fines in sand.	Dunes - High to medium.

Virginia (Portsmouth-Norfolk area) Surficial. 1:100,000. 1975.
sheet 2
Cy. 2

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